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MODELING, ANALYSIS, AND EVALUATION OF RANKINE CYCLE PROPULSION SYSTEMS

VOLUME II: USERS MANUAL

By

J. H. Skinner, R. P. Shah, and J. B. Okesson

February 1972

Prepared for

OFFICE OF AIR PROGRAMS
ENVIRONMENTAL PROTECTION AGENCY
ANN ARBOR, MICHIGAN 48105

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Corporate Research and Development
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Computer program listings for the models derived and analyzed ~~in Volume~~ I are presented. FORTRAN nomenclature, flow diagrams, input and output information, and other user instructions are also included. The manual has been prepared so that the user can link the programs together to form a component or system model, provide the needed input, run the program, and obtain and interpret the results. Each section deals with a particular model. All of the subroutines that are employed in constructing the model are listed. The total memory size requirement for all programs used in the total systems model is approximately 45K. The sections are: fluid property models; reciprocating expander model; turbine expander model; feedpump model; vapor generator model; condenser model; regenerator model; combustor model; transmission model; driver model; parametric design programs; and total system model.

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FOREWORD

This report, "Modeling, Analysis, and Evaluation of Rankine Cycle Propulsion System," describes work carried out under Contract No. EHS-70-111 for the Office of Air Programs, Environmental Protection Agency at Ann Arbor, Michigan. The work was conducted by the Mechanical Engineering Laboratory of Corporate Research and Development of the General Electric Company in Schenectady, New York.

The report consists of two volumes:

Volume I -- Final Report
Volume II -- Users Manual

Volume I includes the derivation of the models and their application to specific designs. Steady-state and transient results are presented. Volume II includes copies of the computer programs, FORTRAN nomenclature, flow diagrams, and other user information.

The Project Officer for this contract was Mr. William Zeber of the Environmental Protection Agency. The Deputy Project Officer was Mr. Kent Jefferies of the National Aeronautics and Space Administration Lewis Research Center in Cleveland, Ohio.

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Section 1

INTRODUCTION

Volume II, Users Manual, contains computer program listings for the models derived and analyzed in Volume I ~~of this report~~ are presented. FORTRAN nomenclature, flow diagrams, input and output information, and other user instructions are also included in this volume.

This manual assumes that the user is familiar with computer programming in general, and understanding of terms such as COMMON, FUNCTION, SUBROUTINE, etc., is taken for granted. The programming language is FORTRAN IV; the models have been run on the General Electric 605 computer (635 compatible).*

The manual has been prepared so that the user can link the programs together to form a component or system model, provide the needed input, run the program, and obtain and interpret the results. The programs as written employ standard programming practices so that persons familiar with the computer language can use the nomenclature listings and flow diagrams to trace logic, identify equations, and make programming changes.

Each section ~~of this volume~~ deals with a particular model. All of the subroutines that are employed in constructing the model are listed. Many subroutines are used in several models, and the nomenclature, flow diagram, and program listing are not repeated in each instance; this information appears in the first section in which the subroutine is mentioned. The "Program Index," in Section 14 of this volume, can be used to locate the user information for any particular program.

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Input data files are generally listed in the same sections as the programs that read them. The only exception is the working fluid data files, which because of their size are listed separately in the Appendix, "Working Fluid Thermodynamic Properties for CP-34, Water, and FC-75," of this volume.

Data files are referenced within the programs by a two-digit integer code. The file names and code are presented in Table 1.

For many programs the COMMON statements are identical to the COMMON for the total system model, MAINSYS, described in Section 13. In these instances the user is referred to MAINSYS for the COMMON nomenclature. The nomenclature listed for each program has been subdivided into three sections:

---

* GE-600 Line FORTRAN IV, Technical Information Bulletin CPB-1006G, General Electric Company Information Systems, September 1964.

1. FORTRAN Variables in COMMON
2. FORTRAN Variables in Argument List
3. Other Selected FORTRAN Variables

from p. 1

In addition, some programs have a section on FORTRAN variables input through READ statements. Employing these lists, the user can find a description and the units for the most important variables.

The total memory size requirement for all programs used in the total systems model is approximately 45K, including the fluid property data for CP-34.

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Table 1

DATA FILES REFERENCED WITHIN PROGRAMS

Integer Code	Data File
Input Files	
04	CP-34 Saturated Fluid Properties
07	CP-34 Superheated Fluid Properties -- Pressure and Temperature
08	CP-34 Superheated Fluid Properties I -- Specific Volume, Enthalpy, Entropy, and Specific Heat
09	CP-34 Superheated Fluid Properties II -- Specific Volume, Enthalpy, Entropy, and Specific Heat
11	Transient Start File
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13	Output File from VAPORG, REGEN, and COND
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Section 2

FLUID PROPERTY MODELS

The thermodynamic property models are entitled:

PROP
PROPST
SATP
SUPPT

The transport and metal property models are programmed as FUNCTIONS.

SUBROUTINE PROP

Subroutine PROP assigns subscripted labels to the CP-34 saturated fluid properties data, file 04, in the Appendix of this volume. Each of the six arrays thus constructed has dimension of 128 and is stored in COMMON with the main system program as follows:

P(128)
T(128)
VLIQ(128)
VVAP(128)
HLIQ(128)
HVAP(128)

PARTICULARS CORRESPONDING TO CHANGE IN FLUID OR FLUID DATA EXTENSION

In case a fluid other than CP-34 is used or the CP-34 saturated fluid properties data list is extended, the dimensions of the arrays in COMMON must be changed correspondingly.

If FC-75 is used as the working fluid, PROP must contain additional operations. Since the units of the values in the FC-75 saturated fluid properties data (Appendix I) are different from those required by the systems program, PROP for FC-75 must contain the following conversions:

$$\underset{\text{(psia)}}{P\ (I)} = \underset{\text{(atm)}}{\left[P\ (I)\right]}\ (14.7)$$

$$\underset{(^{\circ}\text{F})}{T\ (I)} = \underset{(^{\circ}\text{C})}{\left[T\ (I)\right]}\ (1.8) + 32.$$

$$\underset{(\text{ft}^3/\text{lb})}{VLIQ\ (I)} = \underset{\text{(liters/mole)}}{\left[VLIQ\ (I)\right]}\ (0.0382)$$

$$\underset{(\text{ft}^3/\text{lb})}{VVAP\ (I)} = \underset{\text{(liters/mole)}}{\left[VVAP\ (I)\right]}\ (0.0382)$$

$$\underset{\text{(Btu/lb)}}{HLIQ\ (I)} = \underset{\text{(cal/mole)}}{\left[HLIQ\ (I)\right]}\ (4.32 \times 10^{-3})$$

$$\underset{(\text{Btu/lb})}{\text{HVAP (I)}} = \underset{(\text{cal/mole})}{\text{HVAP (I)}}\ (4.32 \times 10^{-3})$$

NOMENCLATURE -- PROP

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of PROP are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

There is no argument list in this program.

FORTRAN Variables in READ Statements:

The FORTRAN variables read in this program are defined in the COMMON list of the main program, MAINSYS.

PROGRAM LISTING -- PROP

```
      SUBROUTINE PROP
*     FLUID CP34
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON FFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      NLINE=128
      DO 20 I=1,NLINE
      READ(04,30)P(I),T(I),VLIQ(I),VVAP(I),HLIQ(I),HVAP(I)
   20 CONTINUE
   30 FORMAT(6F11.5)
      RETURN
      END
```

SUBROUTINE PROPST

Subroutine PROPST assigns subscripted labels to the CP-34 superheated fluid properties data, files 07, 08, and 09. In addition to this it specifically defines, within the program, the first four pressure values. This last is peculiar to CP-34 as the working fluid and was done for convenience at the time the CP-34 superheated data were extended. The pressure array constructed by PROPST has dimension of 70. The first 69 values are actual pressures, while the 70th value is a dummy value inserted for reading convenience. The temperature array has dimension of 33, of which the first 27 are actual temperature values and the remaining six are dummy values.

Each of the other four arrays is two-dimensional with a first dimension of 69, corresponding to the 69 pressure values, and a second dimension of 27, corresponding to the 27 temperature values. All six arrays are stored in COMMON with the main system program as follows:

PTAB (70)
TTAB (33)
VTAB (69,27)
HTAB (69,27)
STAB (69, 27)
CTAB (69, 27)

PARTICULARS CORRESPONDING TO CHANGE IN FLUID OR FLUID DATA EXTENSION

In the case that a fluid other than CP-34 is used or the CP-34 superheated fluid properties data (Appendix I) are extended, the dimensions of the arrays in COMMON must be changed accordingly. These dimensions depend on the quantity of data available and the arrangement of the data for input. For example, to change from CP-34 to water as the working fluid, the dimensions of the fluid property arrays should change to the following:

PTAB (44)
TTAB (40)
VTAB (41,34)
HTAB (41,34)
STAB (41,34)

Figure 11, in Appendix I (p. 390) lists the pressures and temperatures at which we have water-superheated-fluid property values. There are 41 real pressure values and 33 real temperature values in the file. For convenience, the pressures are placed 11 values to a line for four lines. Three dummy values of .0 have been inserted to complete the last line. The temperatures are arranged 10-to-a-line for four lines, with seven dummy values inserted in the last line. Since each line is read completely, 44 pressure values and 40 temperature values are stored in common. Figure 12 in the Appendix (pp. 390 - 405) contains the specific volume, enthalpy, and entropy values corresponding to the pressures and temperatures tabled in Figure 11.

Each line of Figure 12 contains fluid properties for a given pressure and two consecutive temperature values. Since there are only 33 temperature values (an uneven number), there are three dummy values of . 0 to complete the last line of each pressure block. Since each line of Figure 12 is read completely, specific volume, enthalpy, and entropy values read for 41 pressures and 34 temperatures. VTAB, HTAB, and STAB therefore have dimensions of 41 and 34.

If FC-75 is used as the working fluid, the fluid property arrays in COMMON should have the following dimensions:

PTAB (36)
TTAB (20)
VTAB (35, 20)
HTAB (35, 20)
STAB (35, 20)

As in the case of water as the working fluid, these dimensions depend on the arrangement of the data to be input.

In addition to making the proper dimension changes when FC-75 is the working fluid used, PROPST must be changed to contain the conversion statements to change the superheated data to units comparable to those required by the systems program. These conversion statements are:

$$\underset{(\text{psia})}{\text{PTAB (I)}} = \left\{\underset{(\text{atm})}{\text{PTAB (I)}}\right\} (14.\ 7)$$

$$\underset{(^{\circ}\text{F})}{\text{TTAB (I)}} = \left\{\underset{(^{\circ}\text{C})}{\text{TTAB (I)}}\right\} (1.\ 8) + 32.$$

$$\underset{(\text{Btu/lb})}{\text{HTAB (I, J)}} = \left\{\underset{(\text{kcal/mole})}{\text{HTAB (I, J)}}\right\} (4.\ 32)$$

$$\underset{(\text{Btu/lb }^{\circ}\text{F})}{\text{STAB (I, J)}} = \left\{\underset{(\text{cal/mole }^{\circ}\text{C})}{\text{STAB (I, J)}}\right\} (2.\ 4\ \text{E}-3)$$

$$\underset{(\text{ft}^3/\text{lb})}{\text{VTAB(I,J)}} = \left\{\underset{(\text{liters/mole})}{\text{VTAB (I, J)}}\right\} (0.\ 0382)$$

NOMENCLATURE -- PROPST

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of PROPST are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

There is no argument list in this program.

FORTRAN Variables in READ Statements:

The FORTRAN variables read in this program are defined in the COMMON list of the main program, MAINSYS.

PROGRAM LISTING -- PROPST

```
      SUBROUTINE PROPST
•     FLUID CP34
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BI(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      NPSTEP=69
      NTSTEP=27
      PTAB(1)=.1
      PTAB(2)=.3
      PTAB(3)=.5
      PTAB(4)=2.
      READ(07,60)(PTAB(J),J=5,15)
      READ(07,60)(PTAB(J),J=16,26)
      READ(07,60)(PTAB(J),J=27,37)
      READ(07,60)(PTAB(J),J=38,48)
      READ(07,60)(PTAB(J),J=49,59)
      READ(07,60)(PTAB(J),J=60,70)
      READ(07,60)(TTAB(J),J=1,11)
      READ(07,60)(TTAB(J),J=12,22)
      READ(07,60)(TTAB(J),J=23,33)
      DO 30 I=1,37
      DO 30 K=1,NTSTEP
      READ(08,80)VTAB(I,K),HTAB(I,K),STAB(I,K),CTAB(I,K)
 30   CONTINUE
      DO 40 I=37,NPSTEP
      DO 40 K=1,NTSTEP
      READ(09,80)VTAB(I,K),HTAB(I,K),STAB(I,K),CTAB(I,K)
 40   CONTINUE
 60   FORMAT(11F7.1)
 80   FORMAT(4F11.5)
      RETURN
      END
```

SUBROUTINE SATP

Subroutine SATP is the interpolation program for the saturated CP-34 fluid properties (Appendix I). For a given value of any one of three of the thermodynamic properties, it computes the remaining properties of the set by linear interpolation or extrapolation. SATP employs the subroutine PROP.

If extrapolation must be used because of an input value falling outside the range of the saturated fluid properties data, a message will be printed in the output indicating which value is falling above or below the range. NPRINT, a logic variable for printing stored in COMMON, gives the option of suppressing the printing. If NPRINT, the first value of line 00360 of the Data Initial File, is set equal to zero, a message will be printed indicating when an input value goes outside the range of the saturated fluid properties data. If NPRINT is set equal to one, the message will be suppressed.

SATP can be entered with one of three different properties, depending on the input code correspondingly entered. The output consists of the values of the remaining tabled properties for the given input value.

Input	Input Code (NC)	Output
T	0	P, VLIQ, VVAP, HLIQ, HVAP
P	1	T, VLIQ, VVAP, HLIQ, HVAP
HLIQ	2	P, T, VLIQ, VVAP, HVAP

NOMENCLATURE -- SATP

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of SATP are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
HL	Enthalpy of working fluid liquid phase	Btu/lb
HV	Enthalpy of working fluid vapor phase	Btu/lb
NC	Logic variable for input quantities: 0 - TCOND 1 - PCOND 2 - HL	--
PCOND	Pressure of working fluid	lb/in^2
TCOND	Temperature of working fluid	°F

FORTRAN Variable (Cont'd)	Definition	Units
VCOND	Specific volume of working fluid vapor phase	ft^3/lb
VCONDL	Specific volume of working fluid liquid phase	ft^3/lb

PROGRAM LISTING -- SATP

```
      SUBROUTINE SATP(PCOND,TCOND,VCONDL,VCOND,HL,HV,NC)
      COMMON AP,R,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BI(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TURROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL    L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      NLINE=128
      IF(NND.GT.1) GO TO 95
      NND=2
      CALL PROP
   95 CONTINUE
      IF (NC-1)100,200,300
*     SEARCH THE CORRECT INTERVALS
  100 IF(TCOND.LT.T(1)) GO TO 101
      IF(TCOND.LE.T(NLINE)) GO TO 102
      I=NLINE
      IF(NPRINT.NE.0) GO TO 2
      WRITE (6,495)
      GO TO 2
  101 I=2
      IF(NPRINT.NE.0) GO TO 2
      WRITE (6,500)
      GO TO 2
  102 DO 1 I=1,NLINE
      IF (TCOND.LT.T(I)) GOTO 2
    1 CONTINUE
    2 RATIO=(T(I)-TCOND)/(T(I)-T(I-1))
      GO TO 400
  200 IF(PCOND.LT.P(1)) GO TO 201
      IF(PCOND.LE.P(NLINE)) GO TO 202
      I=NLINE
      IF(NPRINT.NE.0) GO TO 5
      WRITE (6,510)
      GO TO 5
```

PROGRAM LISTING -- SATP (Cont'd)

```
201   I=2
      IF(NPRINT.NE.0) GO TO 5
      WRITE (6,520)
      GO TO 5
202   DO 4 I=1,NLINE
      IF (PCOND.LT.P(I)) GOTO 5
  4   CONTINUE
  5   RATIO=(P(I)-PCOND)/(P(I)-P(I-1))
      GO TO 400
300   IF(HL.LT.HLIQ(1)) GO TO 301
      IF(HL.LE.HLIQ(NLINE)) GO TO 302
      I=NLINE
      IF(NPRINT.NE.0) GO TO 8
      WRITE (6,530)
      GO TO 8
301   I=2
      IF(NPRINT.NE.0) GO TO 8
      WRITE (6,540)
      GO TO 8
302   DO 7 I=1,NLINE
      IF(HL.LT.HLIQ(I)) GO TO 8
  7   CONTINUE
  8   RATIO=(HLIQ(I)-HL)/(HLIQ(I)-HLIQ(I-1))
400   PCOND=P(I)-RATIO*(P(I)-P(I-1))
      TCOND=T(I)-RATIO*(T(I)-T(I-1))
      VCONDL=VLIQ(I)-RATIO*(VLIQ(I)-VLIQ(I-1))
      VCOND=VVAP(I)-RATIO*(VVAP(I)-VVAP(I-1))
      HL=HLIQ(I)-RATIO*(HLIQ(I)-HLIQ(I-1))
      HV=HVAP(I)-RATIO*(HVAP(I)-HVAP(I-1))
495   FORMAT (18H T ABOVE SAT TABLE)
500   FORMAT(18H T BELOW SAT TABLE)
510   FORMAT(18H P ABOVE SAT TABLE)
520   FORMAT(18H P BELOW SAT TABLE)
530   FORMAT(18H H ABOVE SAT TABLE)
540   FORMAT(18H H BELOW SAT TABLE)
      RETURN
      END
```

SUBROUTINE SUPPT

Subroutine SUPPT is the interpolation program for the superheated CP-34 fluid properties. For given values of any one of four pairs of thermodynamic properties, it computes the remaining properties of the set by two-way linear interpolation or extrapolation. As in SATP, if an input value falls outside the range of the superheated data, causing the program to use extrapolation, a message is printed in the output indicating this has occurred. By changing the value of NPRINT (as explained in the section on SATP), this print message can be suppressed. SUPPT employs the subroutine PROPST.

Subroutine SUPPT can be entered with one of four different pairs of properties, depending on the input code correspondingly entered. The output consists of the values of the remaining tabled properties for the given pair of inputs.

Input	Input Code (NC)	Output
PTAB, TTAB	1	HTAB, STAB, VTAB
PTAB, STAB	2	TTAB, HTAB, VTAB
PTAB, HTAB	3	TTAB, STAB, VTAB
VTAB, STAB	4	PTAB, TTAB, HTAB

NOMENCLATURE -- SUPPT

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of SUPPT are in the COMMON of MAINSYS.

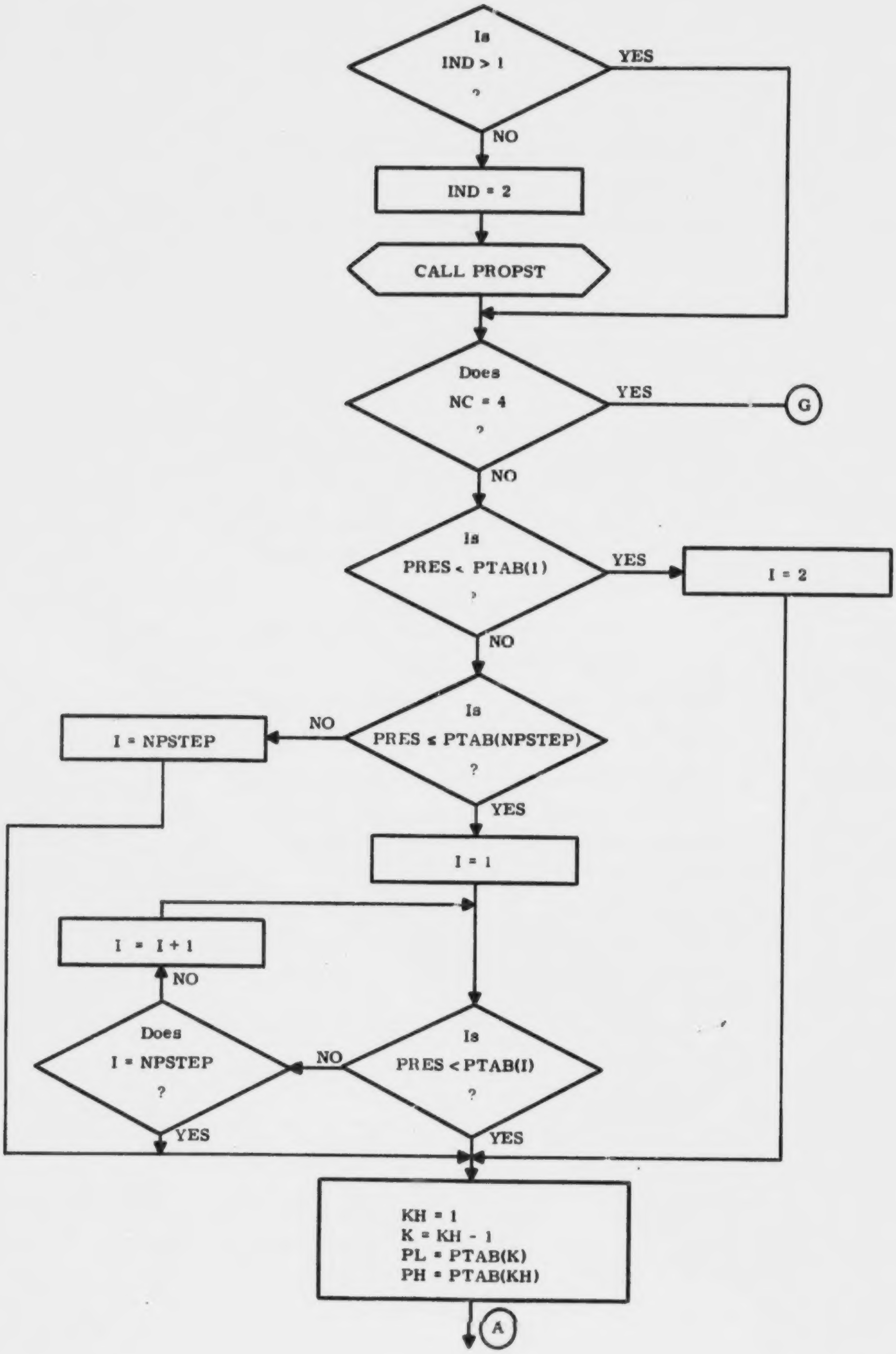
FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
H	Enthalpy	Btu/lb
NC	Logic variable for input quantities 1 - PRES, TEMP 2 - PRES, S 3 - PRES, H 4 - V, S	--
PRES	Pressure	lb/in.^{2}
S	Entropy	Btu/lb °F
TEMP	Temperature	°F
V	Specific volume	ft^3/lb

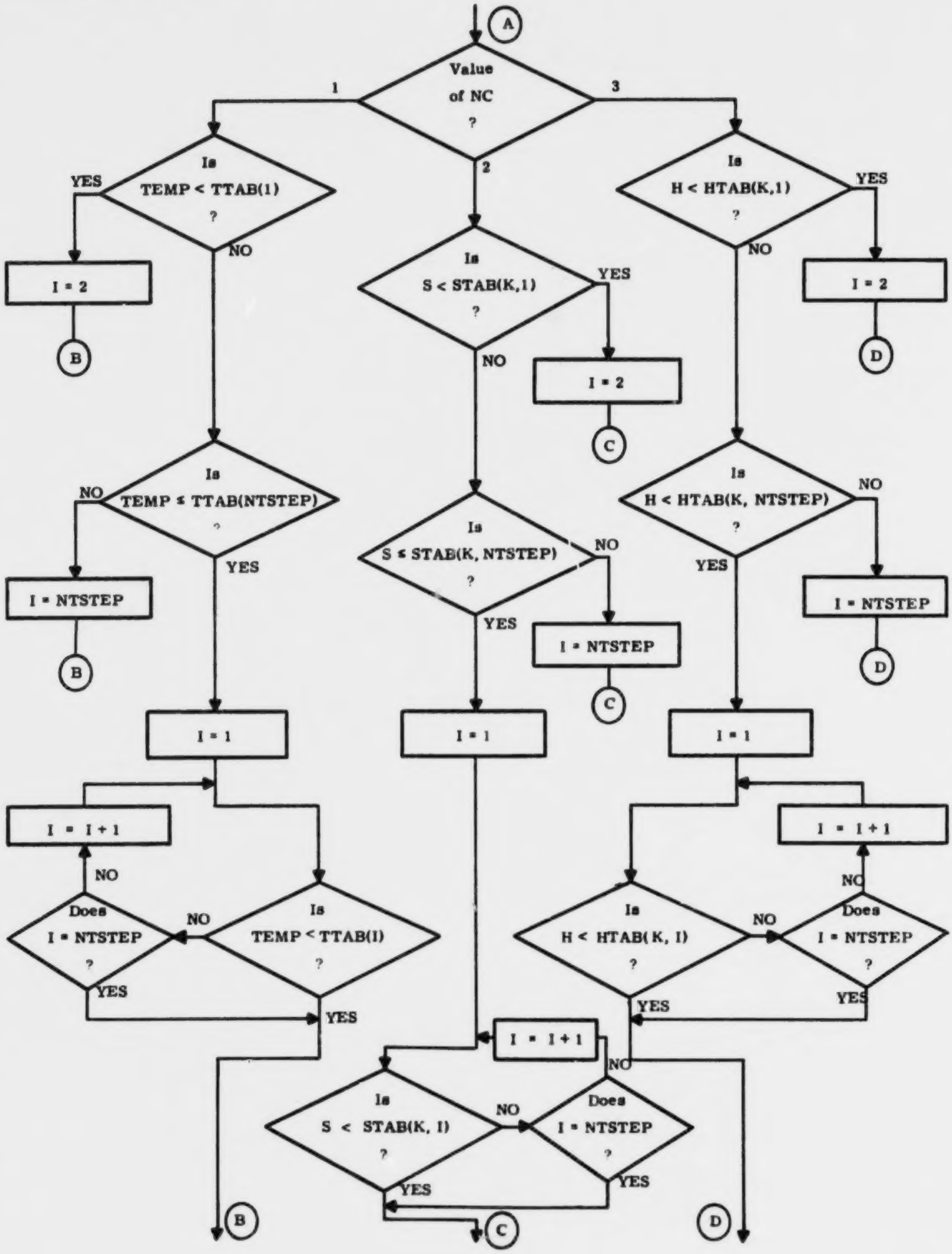
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
C1	New specific heat values based on RATIO1 and RATIO2	Btu/lb °F
C2		Btu/lb °F
CP	Final specific heat value based on C1, C2, and RATIO	Btu/lb °F
H1	New enthalpy values based on RATIO1 and RATIO2	Btu/lb
H2		Btu/lb
K	Subscripts of the tabled pressure values either immediately above or immediately below the given pressure	--
KH		--
LH1	Subscript of the tabled property value that is immediately above the given property value	--
LH2		--
LL1	Subscript of the tabled property value that is immediately below the given property value	
LL2		
PH	Tabled pressure value immediately above the given pressure	lb/in.^{2}
PL	Tabled pressure value immediately below the given pressure	lb/in.^{2}
RATIO	Proportionate distance that the first input property value is from the tabled value below it to the tabled value above it	--
RATIO1	Proportionate distance that the second input property value is from the tabled value below it to the tabled value above it	--
RATIO2		--
S1	New entropy values based on RATIO1 and RATIO2	Btu/lb °F
S2		Btu/lb °F
T1	New temperature values based on RATIO1 and RATIO2	°F
T2		°F
V1	New specific volume based on RATIO1 and RATIO2	ft^3/lb
V2		ft^3/lb

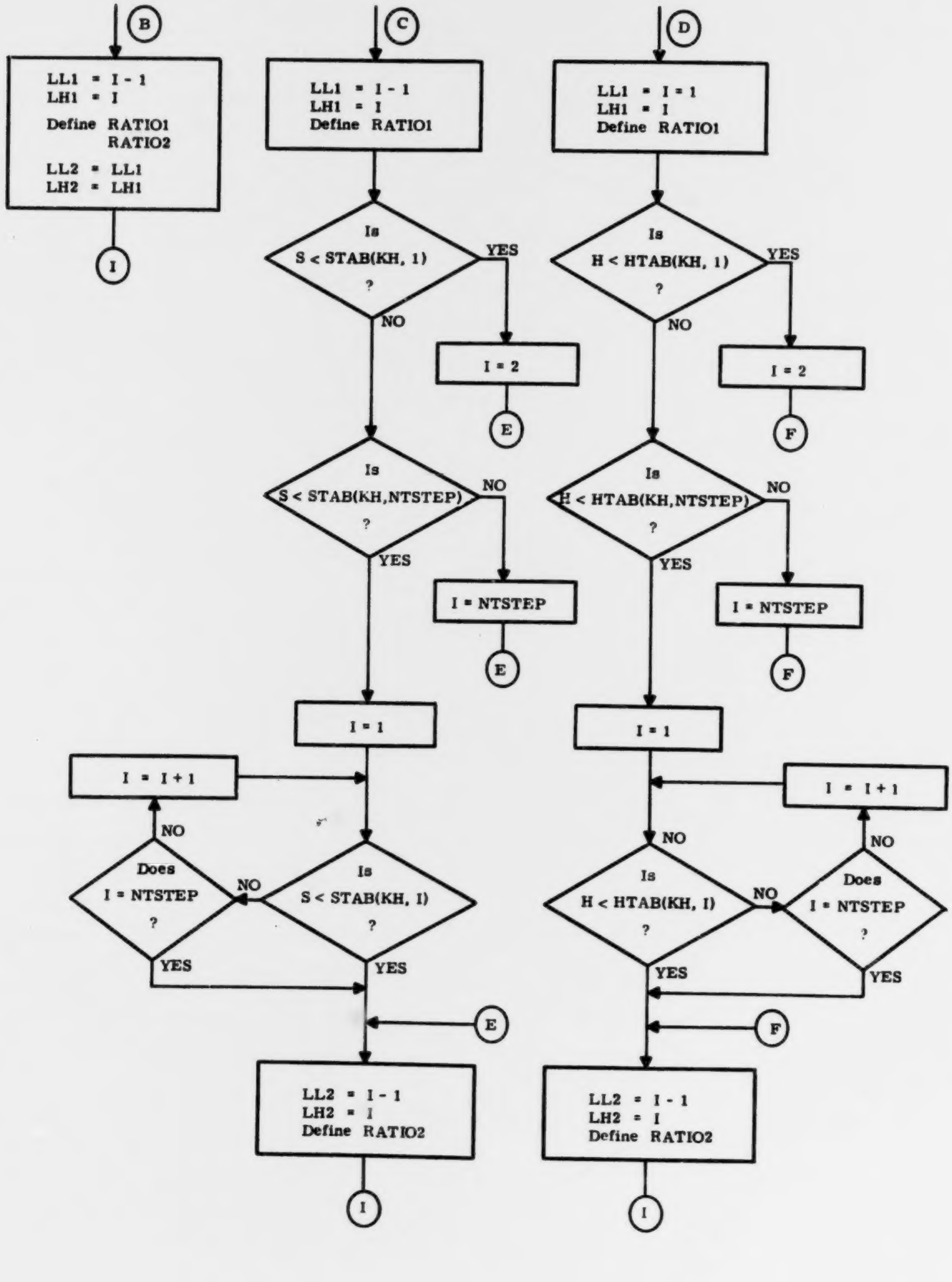
FLOW DIAGRAM -- SUPPT


Is
IND > 1
?
YES
NO
IND = 2
CALL PROPST
Does
NC = 4
?
YES
G
NO
Is
PRES < PTAB(1)
?
YES
I = 2
NO
Is
PRES ≤ PTAB(NPSTEP)
?
NO
I = NPSTEP
YES
I = 1
I = I + 1
NO
Does
I = NPSTEP
?
NO
Is
PRES < PTAB(I)
?
YES
YES
KH = I
K = KH - 1
PL = PTAB(K)
PH = PTAB(KH)
A

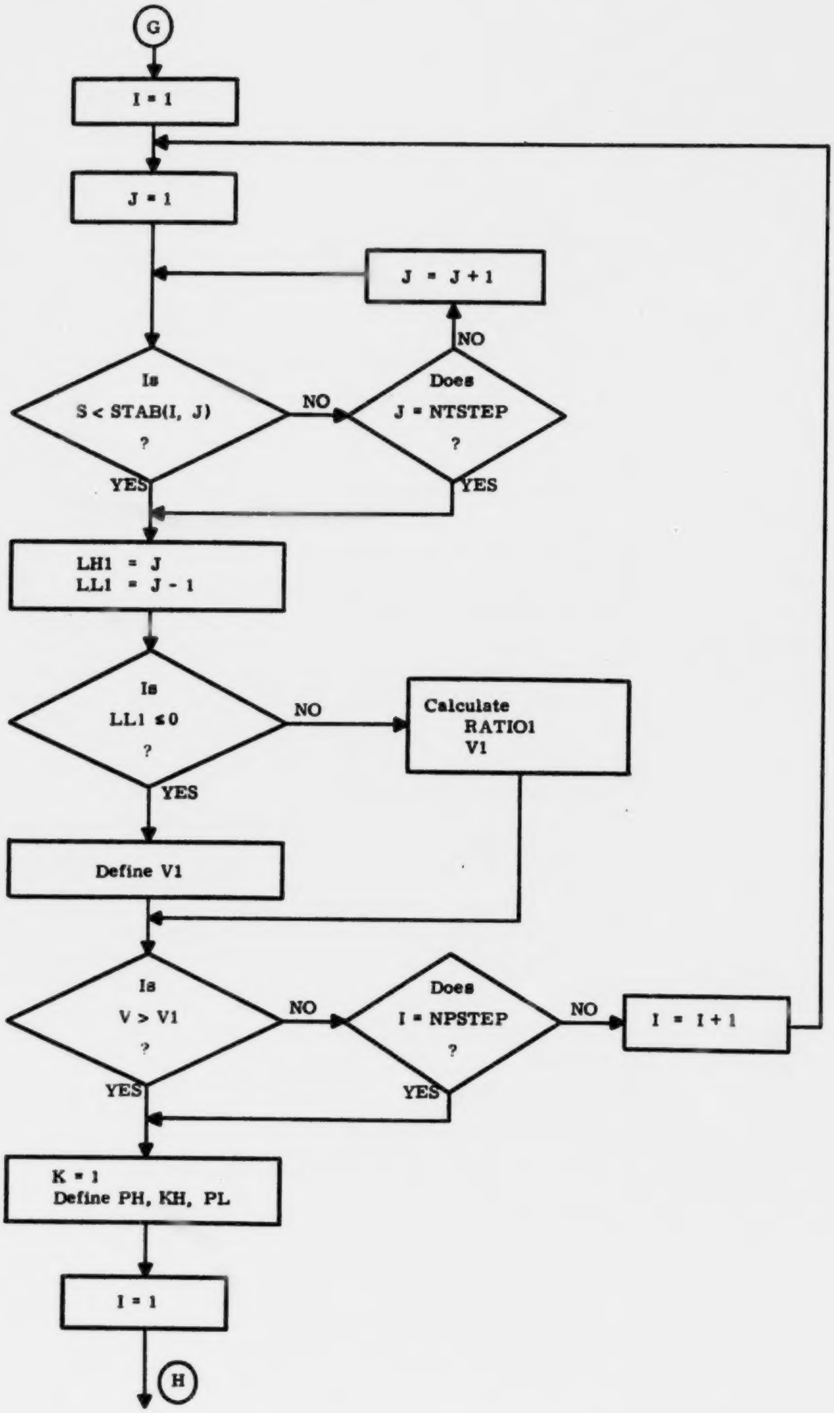
FLOW DIAGRAM -- SUPPT (Cont'd)


A
Value of NC ?
1
2
3
Is TEMP < TTAB(1) ?
YES
NO
I = 2
B
Is TEMP ≤ TTAB(NTSTEP) ?
NO
YES
I = NTSTEP
B
I = 1
I = I + 1
NO
Does I = NTSTEP ?
YES
NO
Is TEMP < TTAB(I) ?
YES
B
Is S < STAB(K,1) ?
YES
NO
I = 2
C
Is S ≤ STAB(K, NTSTEP) ?
NO
YES
I = NTSTEP
C
I = 1
I = I + 1
Is S < STAB(K, I) ?
NO
YES
Does I = NTSTEP ?
NO
YES
C
Is H < HTAB(K,1) ?
YES
NO
I = 2
D
Is H < HTAB(K, NTSTEP) ?
NO
YES
I = NTSTEP
D
I = 1
I = I + 1
Is H < HTAB(K, I) ?
NO
YES
Does I = NTSTEP ?
NO
YES
D

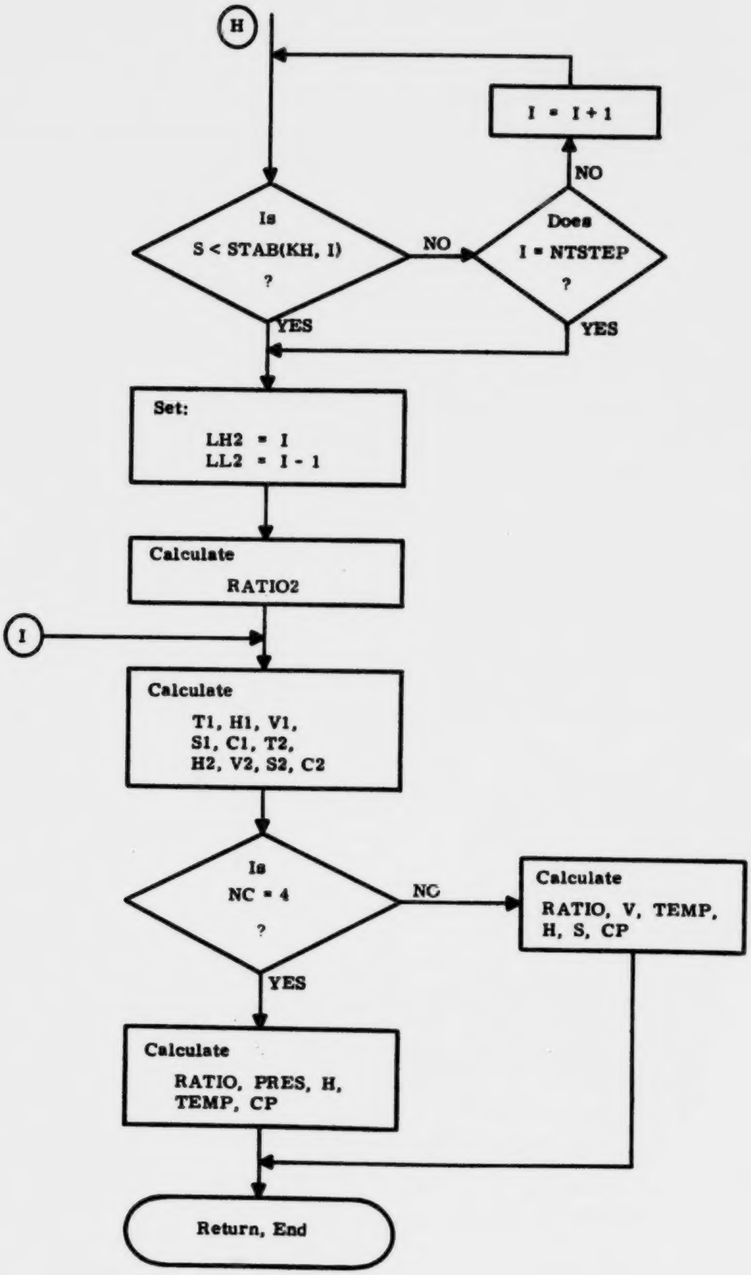
FLOW DIAGRAM -- SUPPT (Cont'd)


B
LL1 = I - 1
LH1 = I
Define RATIO1
RATIO2
LL2 = LL1
LH2 = LH1
I
C
LL1 = I - 1
LH1 = I
Define RATIO1
Is
S < STAB(KH, 1)
?
YES
NO
I = 2
E
Is
S < STAB(KH,NTSTEP)
?
NO
YES
I = NTSTEP
E
I = 1
I = I + 1
NO
Does
I = NTSTEP
?
NO
Is
S < STAB(KH, I)
?
YES
YES
E
LL2 = I - 1
LH2 = I
Define RATIO2
I
D
LL1 = I = 1
LH1 = I
Define RATIO1
Is
H < HTAB(KH, 1)
?
YES
NO
I = 2
F
Is
H < HTAB(KH,NTSTEP)
?
NO
YES
I = NTSTEP
F
I = 1
I = I + 1
NO
Is
H < HTAB(KH, I)
?
NO
Does
I = NTSTEP
?
NO
YES
YES
F
LL2 = I - 1
LH2 = I
Define RATIO2
I

FLOW DIAGRAM -- SUPPT (Cont'd)


G
I = 1
J = 1
J = J + 1
NO
Is
S < STAB(I, J)
?
NO
Does
J = NTSTEP
?
YES
YES
LH1 = J
LL1 = J - 1
Is
LL1 ≤ 0
?
NO
Calculate
RATIO1
V1
YES
Define V1
Is
V > V1
?
NO
Does
I = NPSTEP
?
NO
I = I + 1
YES
YES
K = 1
Define PH, KH, PL
I = 1
H

FLOW DIAGRAM -- SUPPT (Cont'd)


H
I = I + 1
NO
Is
S < STAB(KH, I)
?
NO
Does
I = NTSTEP
?
YES
YES
Set:
LH2 = I
LL2 = I - 1
Calculate
RATIO2
I
Calculate
T1, H1, V1,
S1, C1, T2,
H2, V2, S2, C2
Is
NC = 4
?
NO
Calculate
RATIO, V, TEMP,
H, S, CP
YES
Calculate
RATIO, PRES, H,
TEMP, CP
Return, End

PROGRAM LISTING -- SUPPT

```
      SUBROUTINE SUPPT(PRES,TEMP,H,S,V,NC)
*     FLUID  CP34
      COMMON AP,B,CB,CBR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDB,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STB,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON FFY(10,11),FG,FGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),PFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      IF(IND.GT.1) GO TO 95
      IND=2
      CALL PROPST
   95 CONTINUE
      IF(NC.EQ. 4) GO TO 200
*     WITH PRESSURE AS INPUT
*     SEARCH THIS VALUE FROM TABLE
      IF(PRES.LT.PTAB(1)) GO TO 96
      IF(PRES.LE.PTAB(NPSTEP)) GO TO 97
      I=NPSTEP
      IF(NPRINT.NE.0) GO TO 1
      WRITE (6,210)
      GO TO 1
   96 I=2
      IF(NPRINT.NE.0) GO TO 1
      WRITE (6,220)
      GO TO 1
   97 DO 100 I=1,NPSTEP
      IF(PRES.LT.PTAB(I)) GO TO 1
  100 CONTINUE
    1 KH=I
      K=KH-1
      PL=PTAB(K)
      PH=PTAB(KH)
      GO TO (2,5,10),NC
    2 IF(TEMP.LT.TTAB(1)) GOTO 51
      IF(TEMP.LE.TTAB(NTSTEP)) GO TO 52
       I=NTSTEP
```

PROGRAM LISTING -- SUPPT (Cont'd)

```
      IF(NPRINT.NE.0) GO TO 4
      WRITE (6,230)
      GO TO 4
   51 I=2
      IF(NPRINT.NE.0) GO TO 4
      WRITE (6,240)
      GO TO 4
   52 DO 3 I=1,NTSTEP
      IF(TEMP.LT.TTAB(I)) GO TO 4
    3 CONTINUE
    4 LL1=I-1
      LH1=I
      RATIO1=(TEMP-TTAB(LL1))/(TTAB(LH1)-TTAB(LL1))
      RATIO2=RATIO1
      LL2=LL1
      LH2=LH1
       GO TO 40
    5 IF(S.LT.STAB(K,1)) GO TO 53
      IF(S.LE.STAB(K,NTSTEP)) GO TO 54
       I=NTSTEP
      IF(NPRINT.NE.0) GO TO 7
      WRITE (6,250)
      GO TO 7
   53 I=2
      IF(NPRINT.NE.0) GO TO 7
      WRITE (6,260)
      GO TO 7
   54 DO 6 I=1,NTSTEP
      IF(S.LT.STAB(K,I)) GO TO 7
    6 CONTINUE
    7 LL1=I-1
      LH1=I
      RATIO1=(S-STAB(K,LL1))/(STAB(K,LH1)-STAB(K,LL1))
      IF(S.LT.STAB(KH,1)) GO TO 55
      IF(S.LE.STAB(KH,NTSTEP)) GO TO 56
       I=NTSTEP
      IF(NPRINT.NE.0) GO TO 9
      WRITE (6,270)
      GO TO 9
   55 I=2
      IF(NPRINT.NE.0) GO TO 9
      WRITE (6,280)
      GO TO 9
   56 DO 8 I=1,NTSTEP
      IF(S.LT.STAB(KH,I)) GO TO 9
    8 CONTINUE
    9 LL2=I-1
      LH2=I
      RATIO2=(S-STAB(KH,LL2))/(STAB(KH,LH2)-STAB(KH,LL2))
      GO TO 40
   10 IF(H.LT.HTAB(K,1)) GO TO 57
      IF(H.LE.HTAB(K,NTSTEP)) GO TO 58
       I=NTSTEP
      IF(NPRINT.NE.0) GO TO 12
      WRITE (6,290)
      GO TO 12
   57 I=2
      IF(NPRINT.NE.0) GO TO 12
      WRITE (6,300)
      GO TO 12
```

PROGRAM LISTING -- SUPPT (Cont'd)

```
 58   DO 11 I=1,NTSTEP
      IF(H.LT.HTAB(K,I)) GO TO 12
 11   CONTINUE
 12   LL1=I-1
      LH1=I
      RATIO1=(H-HTAB(K,LL1))/(HTAB(K,LH1)-HTAB(K,LL1))
      IF(H.LT.HTAB(KH,1)) GO TO 59
      IF(H.LE.HTAB(KH,NTSTEP)) GO TO 60
       I=NTSTEP
      IF(NPRINT.NE.0) GO TO 14
      WRITE (6,310)
      GO TO 14
 59   I=2
      IF(NPRINT.NE.0) GO TO 14
      WRITE (6,320)
      GO TO 14
 60   DO 13 I=1,NTSTEP
      IF(H.LT.HTAB(KH,I)) GO TO 14
 13   CONTINUE
 14   LL2=I-1
      LH2=I
      RATIO2=(H-HTAB(KH,LL2))/(HTAB(KH,LH2)-HTAB(KH,LL2))
      GO TO 40
*     WITH SPECIFIC VOLUME AND ENTROPY AS INPUT DATA
*     SEARCH THE CORRECT VALUE OF ENTROPY FIRST
200   DO 24 I=1,NPSTEP
      DO 20 J=1,NTSTEP
      IF(S.LT.STAB(I,J)) GO TO 22
 20   CONTINUE
 22   LH1=J
       LL1=J-1
      IF(LL1.LE.0) GO TO 23
      RATIO1=(S-STAB(I,LL1))/(STAB(I,LH1)-STAB(I,LL1))
      V1=VTAB(I,LL1)+RATIO1*(VTAB(I,LH1)-VTAB(I,LL1))
      GO TO 25
 23   V1=VTAB(I,LH1)
 25   IF(V.GT.V1) GO TO 26
 24   CONTINUE
 26   K=I
      PH=PTAB(K)
      KH=K-1
      PL=PTAB(KH)
      DO 30 I=1,NTSTEP
      IF(S.LT.STAB(KH,I)) GO TO 32
 30   CONTINUE
 32   LH2=I
      LL2=I-1
      RATIO2=(S-STAB(KH,LL2))/(STAB(KH,LH2)-STAB(KH,LL2))
 40   T1=TTAB(LL1)+RATIO1*(TTAB(LH1)-TTAB(LL1))
      H1=HTAB(K,LL1)+RATIO1*(HTAB(K,LH1)-HTAB(K,LL1))
      V1=VTAB(K,LL1)+RATIO1*(VTAB(K,LH1)-VTAB(K,LL1))
      S1=STAB(K,LL1)+RATIO1*(STAB(K,LH1)-STAB(K,LL1))
      C1=CTAB(K,LL1)+RATIO1*(CTAB(K,LH1)-CTAB(K,LL1))
      T2=TTAB(LL2)+RATIO2*(TTAB(LH2)-TTAB(LL2))
      H2=HTAB(KH,LL2)+RATIO2*(HTAB(KH,LH2)-HTAB(KH,LL2))
      V2=VTAB(KH,LL2)+RATIO2*(VTAB(KH,LH2)-VTAB(KH,LL2))
      S2=STAB(KH,LL2)+RATIO2*(STAB(KH,LH2)-STAB(KH,LL2))
      C2=CTAB(KH,LL2)+RATIO2+(CTAB(KH,LH2)-CTAB(KH,LL2))
      IF(NC.EQ.4) GO TO 45
      RATIO=(PRES-PL)/(PH-PL)
```

PROGRAM LISTING -- SUPPT (Cont'd)

```
      V=V1+RATIO*(V2-V1)
      TEMP=T1+RATIO*(T2-T1)
      H=H1+RATIO*(H2-H1)
      S=S1+RATIO*(S2-S1)
      CP=C1+RATIO*(C2-C1)
      GO TO 50
  45  RATIO=(V-V1)/(V2-V1)
      PRES=PH-RATIO*(PH-PL)
      H=H1+RATIO*(H2-H1)
      TEMP=T1+RATIO*(T2-T1)
      CP=C1+RATIO*(C2-C1)
 210  FORMAT (20H P ABOVE SUPPT TABLE)
 220  FORMAT (20H P BELOW SUPPT TABLE)
 230  FORMAT (20H T ABOVE SUPPT TABLE)
 240  FORMAT (20H T BELOW SUPPT TABLE)
 250  FORMAT (20H S ABOVE SUPPT TABLE)
 260  FORMAT (20H S BELOW SUPPT TABLE)
 270  FORMAT (20H S ABOVE SUPPT TABLE)
 280  FORMAT (20H S BELOW SUPPT TABLE)
 290  FORMAT (20H H ABOVE SUPPT TABLE)
 300  FORMAT (20H H BELOW SUPPT TABLE)
 310  FORMAT (20H H ABOVE SUPPT TABLE)
 320  FORMAT (20H H BELOW SUPPT TABLE)
  50  RETURN
      END
```

FUNCTIONS

NOMENCLATURE

The names of the transport and metal property functions, except for a few exceptions, are coded. "F", the first letter of the name, means the subprogram is a function. The second letter indicates the particular property being considered, as follows:

C = Specific heat
D = Specific volume
K = Conductivity
R = Density
V = Viscosity
Y = Surface tension

The third letter (with one exception) tells what material is being used:

A = Air
C = Copper
G = Gas
M = Metal
S = Steel
W = Working fluid

The fourth letter appears only in the names of functions concerning the working fluid and the metals. It tells the phase of the working fluid or which metal is being used, whichever is appropriate:

C = Copper
L = Liquid phase
V = Vapor phase
S = Steel

As an example of this coding, FCWV is the transport function used to calculate the specific heat of the working fluid vapor phase.

One of the exceptions to this coding is the function FKM, which generates the value of the conductivity of the steel-copper matrix. There are three additional functions which do not follow this coding system. FPRS is a Prandtl-number calculation function for water as the working fluid. FPRS1 and FPRS2 are called by FPRS to aid in the Prandtl-number calculation.

SUMMARY OF FUNCTIONS

Table 2 summarizes the parameters of the transport and metal property functions along with the ranges of the parameters at which the functions were compared with reference data.

Table 2

TRANSPORT AND METAL PROPERTY FUNCTIONS
(Parameters, Range, Units)

Name	As a Function of	Compared with Reference Data at Following Conditions	Units
Functions Dealing with CP-34 as Working Fluid (Liquid Phase)			
FCWL	T	T:0-60°F	Btu/lb °F
FDWL	T	T:0-200°F	ft^3/lb
FKWL	T	T:200°F	Btu/hr ft °F
FVWL	T	T:0-600°F	lb/hr ft
FYWL	T	T:60°F	lb/ft
Functions Dealing with CP-34 as Working Fluid (Vapor Phase)			
FCWV	P, T	T:25-100°F P:25-500 psi	Btu/lb °F
FDWV	P, T, NPH	P, T: Ranges of Superheated Tables	ft^3/lb
FKWV	T	T:200°F	Btu/hr ft °F
FVWV	T	T:200°F	lb/hr ft
Functions Dealing with Water as Working Fluid (Liquid Phase)			
FCWL	T	T:60-500°F	Btu/lb °F
FDWL	T	T:60-200°F	ft^3/lb
FKWL	T	T:60-500°F	Btu/hr ft °F
FVWL	T	T:60-500°F	lb/hr ft
FYWL	T	T:200-500°F	lb/ft
Functions Dealing with Water as Working Fluid (Vapor Phase)			
FCWV	P, T	P:14.7-500 psi T:212-1000°F	Btu/lb °F

Table 2 (Cont'd)

Name	As a Function of	Compared with Reference Data at Following Conditions	Units
Functions Dealing with Water as Working Fluid (Vapor Phase) (Cont'd)			
FDWV	(Same function as with CP-34 as Working Fluid)		
FKWV	T	T:500-600°F	Btu/hr ft °F
FVWV	T	T:500°F	lb/hr ft
Functions Dealing with Water as Working Fluid			
FPRS	P, T	--	--
FPRS1	T	--	--
FPRS2	T	--	--
Functions Dealing with FC-75 as Working Fluid (Liquid Phase)			
FCWL	T	T:200°F	Btu/lb °F
FDWL	T	T:10-160°F	ft^3/lb
FKWL	T*	T:constant	Btu/hr ft °F
FVWL	T	T:0-400°F	lb/sec ft
FYWL	T	--	lb/ft
Functions Dealing with FC-75 as Working Fluid (Vapor Phase)			
FCWV	P, T	P:44-294 psi T:115-295°F	Btu/lb °F
FDWV	P, T, NPH	P, T:Ranges of Superheated Tables	ft^3/lb
FKWV	T	T:212-312°F	Btu/hr ft °F
FVWV	T	T:220-460°F	lb/sec ft
Functions Dealing with Air			
FCA	T	T:0-200°F	Btu/lb °F
FDA	T	T:0-200°F	ft^3/lb
FKA	T	T:0-200°F	Btu/hr ft °F
FVA	T	T:0-800°F	lb/hr ft

---

*The effect of temperature on the conductivity of FC-75 liquid phase is not included in the function, even though it is referenced as a parameter.

Table 2 (Cont'd)

Name	As of Function of	Compared with Reference Data at Following Conditions	Units
Functions Dealing with Combustion Gas			
FCG	T, RFA	RFA:0.0504 T:0-1500°F	Btu/lb °F
FDG	T, RFA	RFA:0.0504 T:0-200°F	ft^3/lb
FKG	T	T:0-1500°F	Btu/hr ft °F
FVG	T	T:0-200°F	lb/hr ft
Functions Dealing with Copper			
FCMC	T*	T:Constant	Btu/lb °F
FKC	T	T:0-200°F	Btu/hr ft °F
FRMC	T*	T:Constant	lb/ft^3
Functions Dealing with Steel			
FCMS	T*	T:Constant	Btu/lb °F
FKS	T	T:0-200°F	Btu/hr ft °F
FRMS	T*	T:Constant	lb/ft^3
Function Dealing with Steel-copper Matrix			
FKM	T	T:0-200°F	Btu/hr ft °F

---

*The effect of temperature on the specific heat and density of metals is not included in the functions, even though it is referenced as a parameter.

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PROGRAM LISTING -- FUNCTIONS

```
      FUNCTION FVWL(T)
*     VISCOSITY OF WORKING FLUID LIQUID - CP-34 (LB/HR-FT)
      FVWL=2.4112+T*(-1.3406E-2+T*(2.7889E-5-1.9831E-8*T))
      RETURN
      END
      FUNCTION FKWL(T)
*     CONDUCTIVITY OF WORKING FLUID LIQUID - CP-34 (BTU/HR-FT-F)
      FKWL=7.95E-2+(T-200.)*(8.0E-5+3.4E-7*(T-200.))
      RETURN
      END
      FUNCTION FCWL(T)
*     SPECIFIC HEAT OF WORKING FLUID LIQUID - CP-34 (BTU/LB-F)
      FCWL=0.29+T*(4.268E-4+T*(-4.286E-7+1.472E-9*T))
      RETURN
      END
      FUNCTION FDWL(T)
*     SPECIFIC VOLUME OF WORKING FLUID LIQUID - CP-34 (FT**3/LB)
      CALL SATP(P,T,FDWLA,DV,HL,HV,0)
      FDWL=FDWLA
      RETURN
      END
      FUNCTION FYWL(T)
*     SURFACE TENSION OF WORKING FLUID LIQUID - CP-34 (LB/FT)
*     NOTE THAT THIS EXPRESSION SHOULD BE CHECKED FOR CONSISTENT
*     UNITS
      IF (T.GE.584.) GO TO 10
      FYWL=2.318E-4*(((1.-T/584.)/.882)**(1.3184))
      FYWL=FYWL*10.
      GO TO 20
 10   FYWL=2.318E-4
      FYWL=FYWL*10.
 20   RETURN
      END
      FUNCTION FVWV(T)
*     VISCOSITY OF WORKING FLUID VAPOR - CP-34 (LB/HR-FT)
      FVWV=7.9E-5*T+4.41E-2
      RETURN
      END
      FUNCTION FKWV(T)
*     CONDUCTIVITY OF WORKING FLUID VAPOR - CP-34 (BTU/HR-FT-F)
      FKWV=1.882E-2+(T-200.)*(5.322E-5+1.0E-8*(T-200.))
      RETURN
      END
      FUNCTION FCWV(P,T)
*     SPECIFIC HEAT OF WORKING FLUID VAPOR - CP-34 (BTU/LB-F)
      FCPV1=.1719+T*(4.545E-4-2.381E-7*T)
      FCPV2=.2891+T*(1.206E-4+2.732E-8*T)
      FCPV3=1.964-T*(5.209E-3-4.356E-6*T)
      IF(P-200.)10,10,30
 10   FCWV=((200.-P)*FCPV1+(P-.1)*FCPV2)/199.9
      RETURN
 30   FCWV=((500.-P)*FCPV2+(P-200.)*FCPV3)/300.
      RETURN
      END
```

PROGRAM LISTING -- FUNCTIONS (Cont'd)

```
      FUNCTION FCWL(T)
*     SPECIFIC HEAT OF WORKING FLUID LIQUID - WATER (BTU/LB-F)
      FCWL=9.99+T*(2.8333E-4+T*(-1.062E-6+2.604E-9*T))
      FCWL=FCWL/10.
      RETURN
      END
      FUNCTION FVWL(T)
*     VISCOSITY OF WORKING FLUID LIQUID - WATER (LB/HR-FT)
      FVWL=1./(.08+T*(3.785E-3+T*(1.3365E-5-5.864E-9*T)))
      RETURN
      END
      FUNCTION FKWL(T)
*     CONDUCTIVITY OF WORKING FLUID LIQUID - WATER (BTU/HR-FT-F)
      FKWL=3.2+T*(5.96E-3+T*(-1.125E-5+1.042E-9*T))
      FKWL=FKWL/10.
      RETURN
      END
      FUNCTION FDWL(T)
*     SPECIFIC VOLUME OF WORKING FLUID LIQUID - WATER (FT**3/LB)
      CALL SATP(P,T,FDWLA,DV,HL,HV,0)
      FDWL=FDWLA
*     NOTE IT IS ASSUMED TEMPERATURE WILL BE THE INDEPENDANT VARIABLE
      RETURN
      END
      FUNCTION FYWL(T)
*     SURFACE TENSION OF WORKING FLUID LIQUID - WATER (LB/FT)
      FYWL=5.4612E-3-T*(6.276E-6+3.224E-9*T)
      RETURN
      END
      FUNCTION FVWV(T)
*     VISCOSITY OF WORKING FLUID VAPOR - WATER (LB/HR-FT)
      FVWV=5./9.*(T-32.)
      FVWV=2.42E-4*(80.4+.407*FVWV)
      RETURN
      END
      FUNCTION FKWV(T)
*     CONDUCTIVITY OF WORKING FLUID VAPOR - WATER (BTU/HR-FT-F)
      FKWV=7.124E-3+T*(2.585E-5+3.950E-9*T)
      RETURN
      END
      FUNCTION FCWV(P,T)
*     SPECIFIC HEAT OF WORKING FLUID VAPOR - WATER (BTU/LB-F)
      FCWV=FKWV(T)*FPRS(P,T)/FVWV(T)
      RETURN
      END
      FUNCTION FPRS(P,T)
*     PRANDTL NUMBER FUNCTION FOR WORKING FLUID - WATER
      P1=1000.
      P2=500.
      FPRSL=0.91
      FPRS=FPRS1(T)
      FPRS=FPRS+(FPRS-FPRS2(T))*((P-P1)/(P1-P2))
      IF(FPRS.LT.FPRSL) FPRS=FPRSL
      RETURN
      END
      FUNCTION FPRS1(T)
*     FUNCTION USED IN PRANDTL NUMBER CALCULATION FOR WORKING
*       FLUID - WATER
      FPRS1=4.432+T*(-7.821E-3+4.429E-6*T)
      RETURN
```

PROGRAM LISTING -- FUNCTIONS (Cont'd)

```
      END
      FUNCTION FPRS2(T)
*     FUNCTION USED IN PRANDTL NUMBER CALCULATION FOR WORKING
*       FLUID - WATER
      FPRS2=2.4386+T*(-3.381E-3+1.985E-6*T)
      RETURN
      END
      FUNCTION FVWL(T)
*     VISCOSITY OF WORKING FLUID LIQUID - FC-75 (LB/HR-FT)
      IF(T.LE.250.) GO TO 10
      FVWL=EXP(.97404-4.5462E-03*T)
      RETURN
   10 IF(T.LE.100.) GO TO 20
      FVWL=EXP(1.73261-7.5805E-03*T)
      RETURN
   20 FVWL=EXP(2.24071-1.2661E-02*T)
      RETURN
      END
      FUNCTION FKWL(T)
*     CONDUCTIVITY OF WORKING FLUID LIQUID - FC-75 (BTU/HR-FT-F)
      FKWL=.036
      RETURN
      END
      FUNCTION FCWL(T)
*     SPECIFIC HEAT OF WORKING FLUID LIQUID - FC-75 (BTU/LB-F)
      FCWL=.2255+2.5E-04*T
      RETURN
      END
      FUNCTION FDWL(T)
*     SPECIFIC VOLUME OF WORKING FLUID LIQUID - FC-75 (FT**3/LB)
      FDWL=1./(116.343-8.4333E-02*T)
      RETURN
      END
      FUNCTION FYWL(T)
*     SURFACE TENSION OF WORKING FLUID LIQUID - FC-75 (LB/FT)
      FYWL=6.86E-05*(20.006-6.6827E-02*T)
      RETURN
      END
      FUNCTION FVWV(T)
*     VISCOSITY OF WORKING FLUID VAPOR - FC-75 (LB/HR-FT)
      IF(T.LE.300.) GO TO 10
      FVWV=2.14214E-02*EXP(1.32718E-03*T)
      RETURN
   10 FVWV=.02083+3.75E-05*T
      RETURN
      END
      FUNCTION FCWV(P,T)
*     SPECIFIC HEAT OF WORKING FLUID VAPOR - FC-75 (BTU/LB-F)
      P=P/14.7
      T=(T-32.)*5./9.
      IF(P.GT.5.)GO TO 10
      FCWV=9.6289E-02+5.0906E-05*T
      GO TO 110
   10 FCPV3=T/(-1718.35+14.5669*T)
      IF(P.GE.15.)GO TO 20
      IF(T.GT.195.)GO TO 30
      FCPV1= .1655-3.0E-04*T
      GO TO 40
   30 FCPV1= .1003+4.0764E-05*T
```

PROGRAM LISTING -- FUNCTIONS (Cont'd)

```
 40   FCPV2=T/(-827.576+11.8346*T)
      IF(P-10.)50,50,60
 50   FCWV=((10.-P)*FCPV1+(P-5.)*FCPV2)/5.
      GO TO 110
 60   FCWV=((15.-P)*FCPV2+(P-10.)*FCPV3)/5.
      GO TO 110
 20   IF(T-255.)120,120,130
120   FCPV4=.155
      GO TO 70
130   IF(T-265.)80,80,90
 80   FCPV4=.7925-.0025*T
      GO TO 70
 90   FCPV4=.2183-3.33E-04*T
 70   IF(P.GT.20.)GO TO 100
      FCWV=((20.-P)*FCPV3+(P-15.)*FCPV4)/5.
      GO TO 110
100   FCWV=FCPV4
110   P=P*14.7
      T=32.+T*9./5.
      FCWV=FCWV*4.32*5./9.
      RETURN
      END
      FUNCTION FDWV(P,T,NPH)
*     SPECIFIC VOLUME OF WORKING FLUID VAPOR - FC-75 (FT**3/LB)
      GO TO (20,20,30),NPH
 20   CALL SATP(P,T,DL,FDWVA,HL,HV,0)
      FDWV=FDWVA
      RETURN
 30   CALL SUPPT(P,T,H,S,FDWVA,1)
      FDWV=FDWVA
      RETURN
      END
      FUNCTION FKWV(T)
*     CONDUCTIVITY OF WORKING FLUID VAPOR - FC-75 (BTU/HR-FT-F)
      FKWV=-8.8246E-03+7.9822E-05*T
      RETURN
      END
      FUNCTION FKA(T)
*     CONDUCTIVITY OF AIR (BTU/HR-FT-F)
      FKA=1.336E-2+T*(2.456E-5-4.120E-9*T)
      RETURN
      END
      FUNCTION FCA(T)
*     SPECIFIC HEAT OF AIR (BTU/LB-F)
      FCA=5.*(T-32.)/9.+273.
      FCA=(6.27+FCA*(2.09E-3-4.59E-7*FCA))/29.
      RETURN
      END
      FUNCTION FVA(T)
*     VISCOSITY OF AIR (LB/HOUR-FT)
      FVA=3.76E-2+T*(6.4E-5+T*(-2.085E-8+4.062E-12*T))
      RETURN
      END
      FUNCTION FDA(T)
*     SPECIFIC VOLUME OF AIR (FT**3/LB)
      FDA=(460.+T)/(.0862*460.)
      RETURN
      END
      FUNCTION FVG(T)
```

PROGRAM LISTING -- FUNCTIONS (Cont'd)

```
*     VISCOSITY OF GAS (LB/HR-FT)
      FVG=.0376+T*(6.401E-5+T*(-2.85E-8+4.063E-12*T))
      RETURN
      END
      FUNCTION FKG(T)
*     CONDUCTIVITY OF GAS (BTU/HR-FT-F)
      FKG=.0129+T*(2.50E-5+T*(-6.399E-9+8.68E-13*T))
      RETURN
      END
      FUNCTION FCG(T,RFA)
*     SPECIFIC HEAT OF GAS (BTU/LB-F)
      FCG=(1.28*RFA+1.00)*FCA(T)
      RETURN
      END
      FUNCTION FDG(T,RFA)
*     SPECIFIC VOLUME OF GAS (FT**3/LB)
      FDG=FDA(T)/(-.0911*RFA+1.00)
      RETURN
      END
      FUNCTION FKS(T)
*     CONDUCTIVITY OF STEEL (BTU/HR-FT-F)
      FKS=24.95+T*(-2.902E-3+T*(-4.017E-6+1.64E-9*T))
      RETURN
      END
      FUNCTION FKC(T)
*     CONDUCTIVITY OF COPPER (BTU/HR-FT-F)
      FKC=227.5+T*(-3.2E-2+1.E-5*T)
      RETURN
      END
      FUNCTION FCMS(T)
*     SPECIFIC HEAT OF STEEL (BTU/LB-F)
      FCMS=.122
      RETURN
      END
      FUNCTION FKM(T)
*     CONDUCTIVITY OF STEEL-COPPER MATRIX (BTU/HR-FT-F)
      FKM=.5*(FKC(T)+7.133*(T**3)*1.E-9-9.2*(T**2)*1.E-6)
      FKM=FKM+.5*(-16.68*T*1.E-3+42.65)
      RETURN
      END
      FUNCTION FCMC(T)
*     SPECIFIC HEAT OF COPPER (BTU/LB-F)
      FCMC=.0915
      RETURN
      END
      FUNCTION FRMS(T)
*     DENSITY OF STEEL (LB/FT**3)
      FRMS=487.
      RETURN
      END
      FUNCTION FRMC(T)
*     DENSITY OF COPPER (LB/FT**3)
      FRMC=559.
      RETURN
      END
      FUNCTION FDWV(P,T,NPH)
*     SPECIFIC VOLUME OF WORKING FLUID VAPOR (FT**3/LB)
      GO TO (20,20,30),NPH
```

PROGRAM LISTING -- FUNCTIONS (Cont'd)

```
  20 CALL  SATP(P,T,DL,FDWVA,HL,HV,0)
*       NOTE  IT IS ASSUMED TEMPERATURE WILL BE THE INDEPENDANT VARIABLE
      FDWV=FDWVA
      RETURN
  30  CALL  SUPPT(P,T,H,S,FDWVA,1)
      FDWV=FDWVA
      RETURN
      END
```

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Section 3

RECIPROCATING EXPANDER MODEL

MAIN PROGRAM -- ENGINE

The reciprocating expander model is entitled ENGINE. The model employs the following subroutines:

SUPPT
DOME
FVWV
FKWV

In ENGINE, iterations are performed to determine the value of VEV. The accuracy of the iteration is determined by the value of ERROR, which has been set at 0.02 in the model. The variable ITER2 records the number of iterations, and the program is stopped when ITER2 reaches 100.

NOMENCLATURE -- ENGINE

FORTRAN Variables in COMMON:

FORTRAN variables in COMMON of ENGINE are in COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
FLOWR	Mass flow rate through engine	lb/sec
HE	Exhaust enthalpy	Btu/lb
HI	Inlet enthalpy	Btu/lb
PE	Exhaust pressure	$lb/in.^2$
PI	Inlet pressure	$lb/in.^2$
R	Engine intake ratio	--
RPM	Expander rotational speed	rpm
SE	Exhaust entropy	Btu/lb °F
SI	Inlet entropy	Btu/lb °F
TE	Exhaust temperature	°F
TI	Inlet temperature	°F
TORQUE	Torque	ft lb

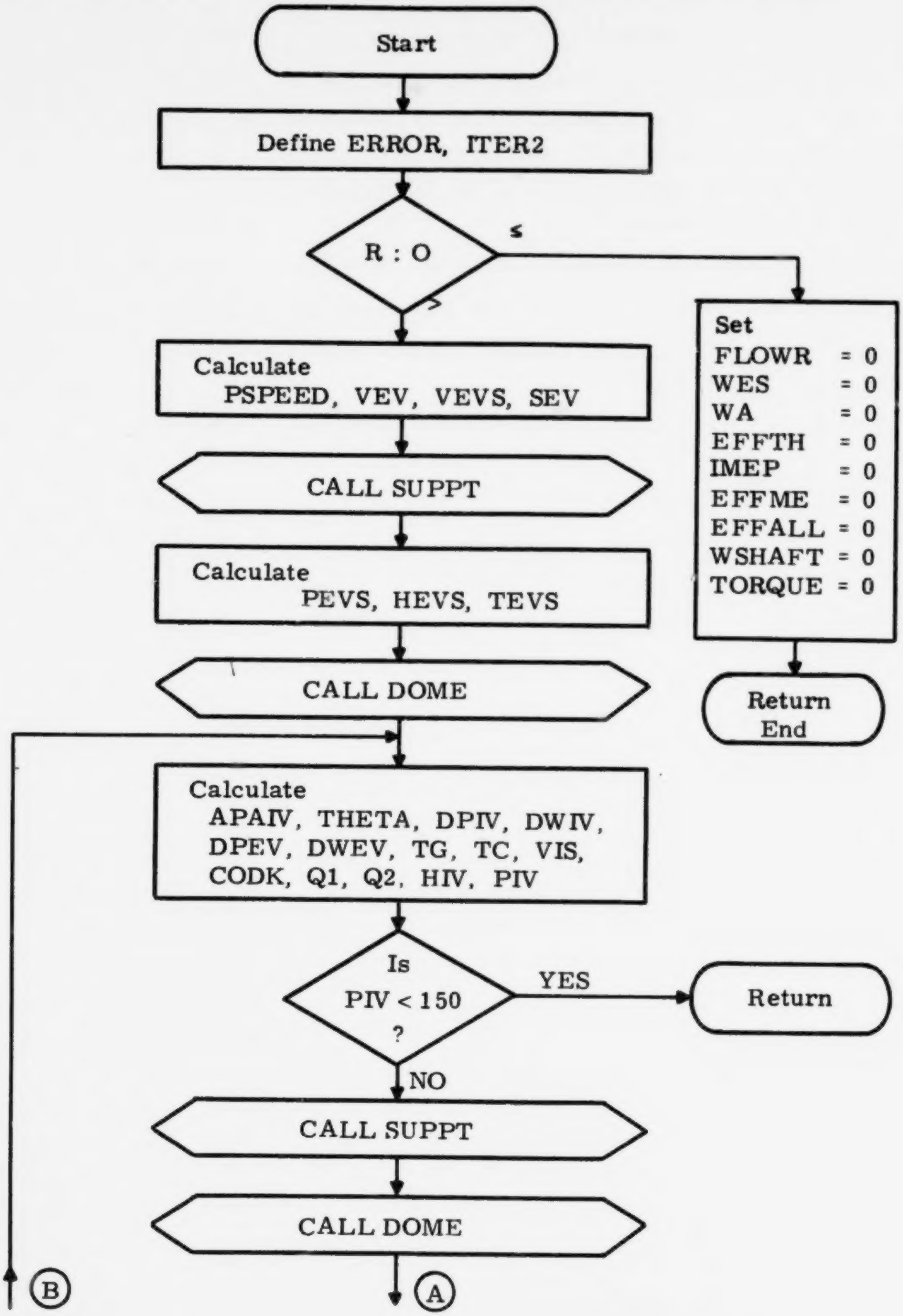
FORTRAN Variable	Definition	Units
VE	Exhaust specific volume	ft^3/lb
VI	Inlet specific volume	ft^3/lb
XE	Exhaust quality	--

Other Selected FORTRAN Variables:

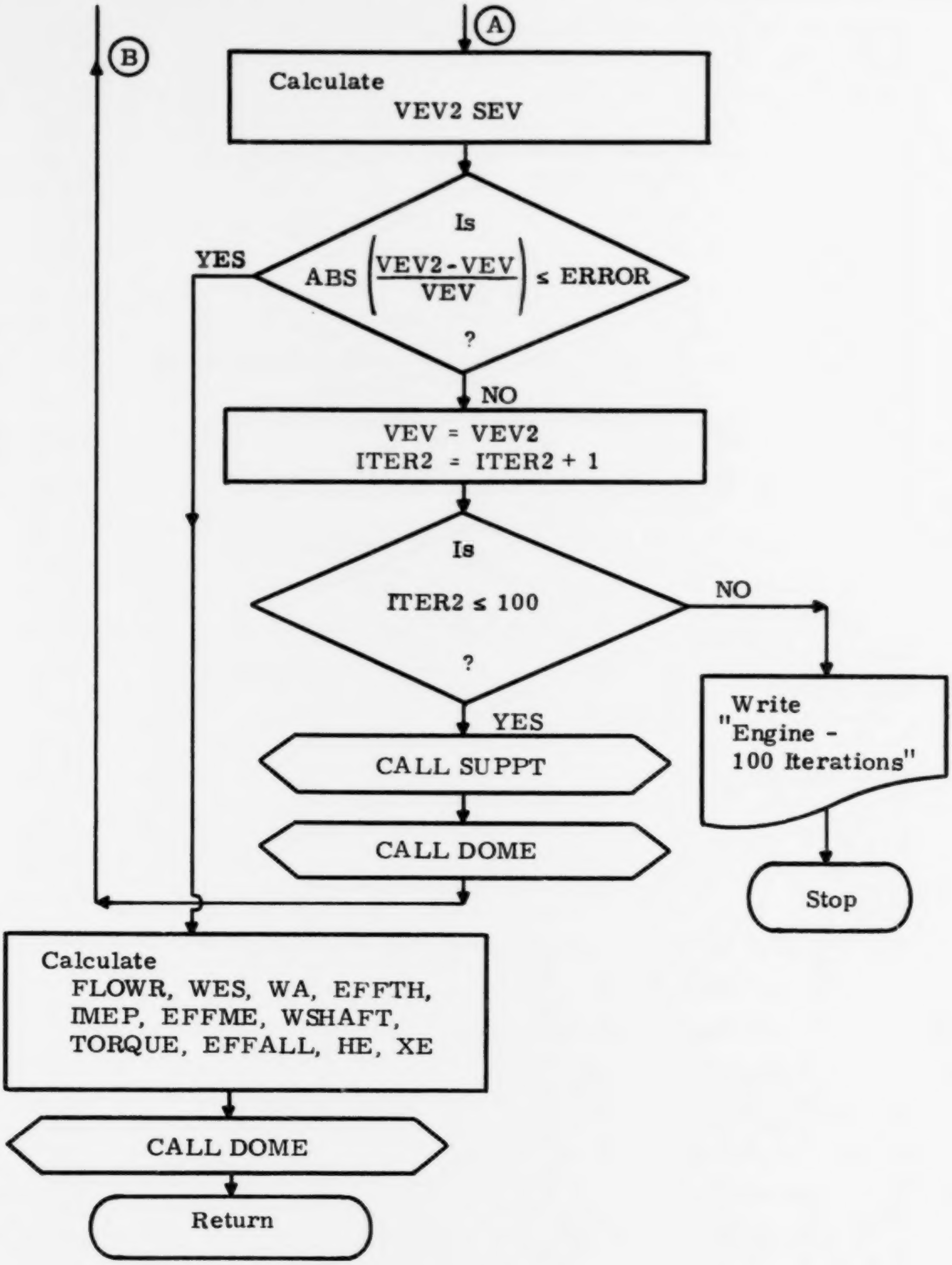
FORTRAN Variable	Definition	Units
APAIV	Ratio of piston area to average inlet valve area	--
CODK	Working fluid conductivity	Btu/hr ft °F
DPEV	Pressure drop across exhaust valve	lb/ft^2
DPIV	Pressure drop across inlet valve	lb/ft^2
DWEV	Work loss across exhaust valve	Btu/lb
DWIV	Work loss across inlet valve	Btu/lb
EFFALL	Overall expander efficiency	--
EFFME	Mechanical efficiency	--
EFFTH	Thermal efficiency	--
ERROR	Convergence criterion for VEV	--
HEV	Enthalpy at end of stroke	Btu/lb
HEVS	Enthalpy at end of stroke for isentropic expansion	Btu/lb
HIV	Enthalpy after intake	Btu/lb
IMEP	Indicator mean effective pressure	psi
ITER2	Counter of internal iterations	--
PEVS	Pressure at end of stroke	psi
PIV	Pressure after intake	psi
PSPEED	Piston speed	ft/min
Q1	Heat loss	Btu/lb
Q2	Heat loss during intake valve	Btu/lb
SEV	Entropy at end of stroke for isentropic expansion	Btu/lb °F

FORTRAN Variable	Definition	Units
TC	Average wall temperature	°F
TEV	Temperature at end of stroke	°F
TEVS	Temperature at end of stroke for isentropic expansion	°F
TG	Average working fluid temperature	°F
THETA	Crank angle for intake opening	degrees
VEV	Specific volume at end of stroke	ft^3/lb
VEV2	Previous specific volume at end of a stroke	ft^3/lb
VEVS	Specific volume at end of stroke for isentropic expansion	ft^3/lb
VIS	Working fluid viscosity	lb/hr ft
VIV	Specific volume after intake	ft^3/lb
WA	Indicator work	Btu/lb
WES	Isentropic work	Btu/lb
WSHAFT	Shaft work	Btu/lb

FLOW DIAGRAM -- ENGINE (for Reciprocating EXPANDER)


Start
Define ERROR, ITER2
R : O
≤
>
Set
FLOWR = 0
WES = 0
WA = 0
EFFTH = 0
IMEP = 0
EFFME = 0
EFFALL = 0
WSHAFT = 0
TORQUE = 0
Return
End
Calculate
PSPEED, VEV, VEVS, SEV
CALL SUPPT
Calculate
PEVS, HEVS, TEVS
CALL DOME
Calculate
APAIV, THETA, DPIV, DWIV,
DPEV, DWEV, TG, TC, VIS,
CODK, Q1, Q2, HIV, PIV
Is
PIV < 150
?
YES
Return
NO
CALL SUPPT
CALL DOME
B
A

FLOW DIAGRAM -- ENGINE (for Reciprocating EXPANDER) (Cont'd)



A
B
Calculate
VEV2 SEV
Is
ABS ((VEV2-VEV)/VEV) ≤ ERROR
?
YES
NO
VEV = VEV2
ITER2 = ITER2 + 1
Is
ITER2 ≤ 100
?
NO
YES
CALL SUPPT
CALL DOME
Write
"Engine -
100 Iterations"
Stop
Calculate
FLOWR, WES, WA, EFFTH,
IMEP, EFFME, WSHAFT,
TORQUE, EFFALL, HE, XE
CALL DOME
Return

PROGRAM LISTING -- ENGINE

```
      SUBROUTINE ENGINE(R,RPM,PI,TI,HI,SI,VI,PE,TE,HE,SE,
     1VE,XE,FLOWR,TORQUE)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,CCS,QCI,QTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,QTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NRENDA
      COMMON NRENDG,NO,QP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BI(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGI,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2F(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSFCT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TORROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VPI(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),INO
      COMMON NLINE,NNO,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL IMEP
      ERROR=0.02
      ITER2=0
      IF(R) 175,175,5
    5 PSPEED=RPM*SP1/6.
      VEV=VI/R
      VEVS=VEV
      SEV=SI
      CALL SUPPT(PEV,TEV,HEV,SEV,VEV,4)
      PEVS=PEV
      HEVS=HEV
      TEVS=TEV
   10 CALL DOME(PEV,HEV,TEV,VEV,XEV,DD,1)
      GO TO 60
   50 IF(ITER2.LE.100) GO TO 55
      WRITE(6,52)
   52 FORMAT (22H ENGINE-100 ITERATIONS)
      STOP
   55 CALL SUPPT(PEV,TEV,HEV,SEV,VEV,4)
   57 CALL DOME(PEV,HEV,TEV,VEV,XEV,DD,1)
*     CALCULATE PRESSURE DROP AND WORK LOSS THROUGH VALVES
   60 IF (R.LT..45) GO TO 100
      APALV=6.382*(R**(-.3676))
      GO TO 120
  100 APALV=4.85*(R**(-.779))
  120 X=1.-2.*R
      XY=SQRT((1./X**2)-1.)
      ACST=ATAN(XY)
```

PROGRAM LISTING -- ENGINE (Cont'd)

```
      THETA=ACST*(180./3.1415926)
      IF(THETA.LT.0.) THETA=180.-THETA
      DPIV=.3888*(APAIV**2)*(PSPEED**2)*(VI/(VEV**2))/(THETA**2)
      DWIV=DPIV*VI/778.
      DP=PEV-PE
      IF(DP.GT.0.) GO TO 140
      DP=-DP
      SIGN=1.
      GO TO 160
 140  SIGN=-1.
 160  DPEV=(3.34E-03)*(PSPEED**2)/VEV+SIGN*.39*PSPEED*SQRT(DP/VEV)
      DWEV=DPEV*VEV/778.
      IF(DWEV.LT.0.)DWEV=0.
*
*     ENGINE HEAT LOSS
*
      TG=R*TI+0.5*(1.-R)*(TI+TEVS)
      TC=TI*(400.+156.*(R**2))/550.
      VIS=FVWV(TG)
      CONK=FKWV(TG)
      F=(12.55/AP)**.125
      Q1=1.48*(CONK*VEV/PSPEED)*((PSPEED/(VEV*VIS))**.75)*(TG-TC)*F
      IF(Q1.LT.0.)Q1=0.
      Q2=Q1*(THETA/180.)*(TI-TC)/(TG-TC)
      IF(Q2.GT.Q1) Q2=Q1
      HIV=HI-Q2
      PIV=PI-2.*DPIV/144.
      IF(PIV.LT.150.) GO TO 168
      CALL SUPPT(PIV,TIV,HIV,SIV,VIV,3)
      CALL DOME(PIV,HIV,TIV,VIV,XIV,D0,0)
      VEV2=VIV/R
      SEV=SIV
      IF(ABS((VEV2-VEV)/VEV).LE.ERROR) GO TO 165
      VEV=VEV2
      ITER2=ITER2+1
      GO TO 50
 165  CONTINUE
*     CALCULATE FLOW RATE AND EFFICIENCY
*
      FLOWR=FLOAT(NP)*AP*PSPEED/(VEV*4.8)
      WES=(HI-HEVS)+VEVS*(PEVS-PE)*(144./778.)
      WA=WES-DWIV-DWEV-Q1
      EFFTH=WA/WES
      IMEP=WA*778./(VEV*144.)
      EFFME=1.-(PSPEED*(174./IMEP+1.6)*(1.E-05)+.012+5.46/IMEP)
*
*     SHAFT WORK AND OVERALL EFFICIENCY
*
      WSHAFT=EFFME*WA
      TORQUE=(WSHAFT*FLOWR*778.)/(RPM*2.*3.14*60.)
      EFFALL=EFFTH*EFFME
      HE=HI-WA-Q1
      XE=1.0
      FLOWR=FLOWR/3600.
      CALL DOME(PE,HE,TE,VE,XE,SE,0)
 168  CONTINUE
      RETURN
 175  FLOWR=0.
      WES=0.
      WA=0.
```

PROGRAM LISTING -- ENGINE (Cont'd)

```
EFFTH=0.
IMEP=0.
EFFME=0.
EFFALL=0.
WSHAFT=0.
TORQUE=0.
RETURN
END
```

SUBROUTINE -- DOME

Subroutine DOME employs the subroutines SATP and SUPPT. DOME is used to determine if the working fluid is in the gas or two-phase flow region.

NOMENCLATURE -- DOME

FORTRAN Variables in COMMON:

There is no COMMON block in DOME.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
H	Enthalpy	Btu/lb
NC	Logic variable 0 - define quality in terms of specific volume of mixture 1 - define quality in terms of enthalpy of mixture	--
P	Pressure	lb/in^2
S	Entropy	Btu/lb °F
T	Temperature	°F
V	Specific volume	ft^3/lb
X	Quality	--

PROGRAM LISTING -- DOME

```
      SUBROUTINE DOME(P,H,T,V,X,S,NC)
      CALL SAIP(P,T1,V1L,V1V,H1L,H1V,1)
      IF(H1V.LT.H) GO TO 100
      IF(NC.EQ.0) GO TO 300
      X=(V-V1L)/(V1V-V1L)
      GO TO 400
300   X=(H-H1L)/(H1V-H1L)
400   T=T1
      V=V1L+X*(V1V-V1L)
      H=H1L+X*(H1V-H1L)
      GO TO 200
100   X=1.
      CALL SUPPT(P,T,H,S,V,3)
200   RETURN
      END
```

Section 4

TURBINE EXPANDER MODEL

MAIN PROGRAM -- TURBIN

The turbine expander model is entitled TURBIN. The model employs the subroutine SUPPT. The turbine model has not been used with the other component models or in MAINSYS; therefore, the COMMON statement in TURBIN is not consistent with the COMMON in the other models. The COMMON in TURBIN and SUPPT must be consistent in order to exercise the turbine expander model.

NOMENCLATURE -- TURBIN

FORTRAN Variables in COMMON of TURBIN:

FORTRAN Variable	Definition	Units
AREAE	Nozzle exit area	in.^{2}
AREAT	Nozzle throat area	in.^{2}
GAMMA	Ratio of specific heats	--
GASC	Gas constant	ft lb/lb °F
HYDEFF	Hydraulic efficiency	--
MACHD	Design mach number	--
MACHNE	Isentropic Mach number	--
NCOEF	Nozzle coefficient	--
NCOEFD	Design nozzle coefficient	--
NOZANG	Inlet angle	radians
PRCRIT	Critical pressure ratio	--
RCOEF	Rotor coefficient	--
ROTDIA	Turbine rotor diameter	ft
SPTVEL	Isentropic spouting velocity	ft/sec
STO	Exit entropy	Btu/lb °F
TIPSPD	Turbine tip speed	ft/sec

For the remaining FORTRAN Variables in COMMON, see the COMMON of MAINSYS.

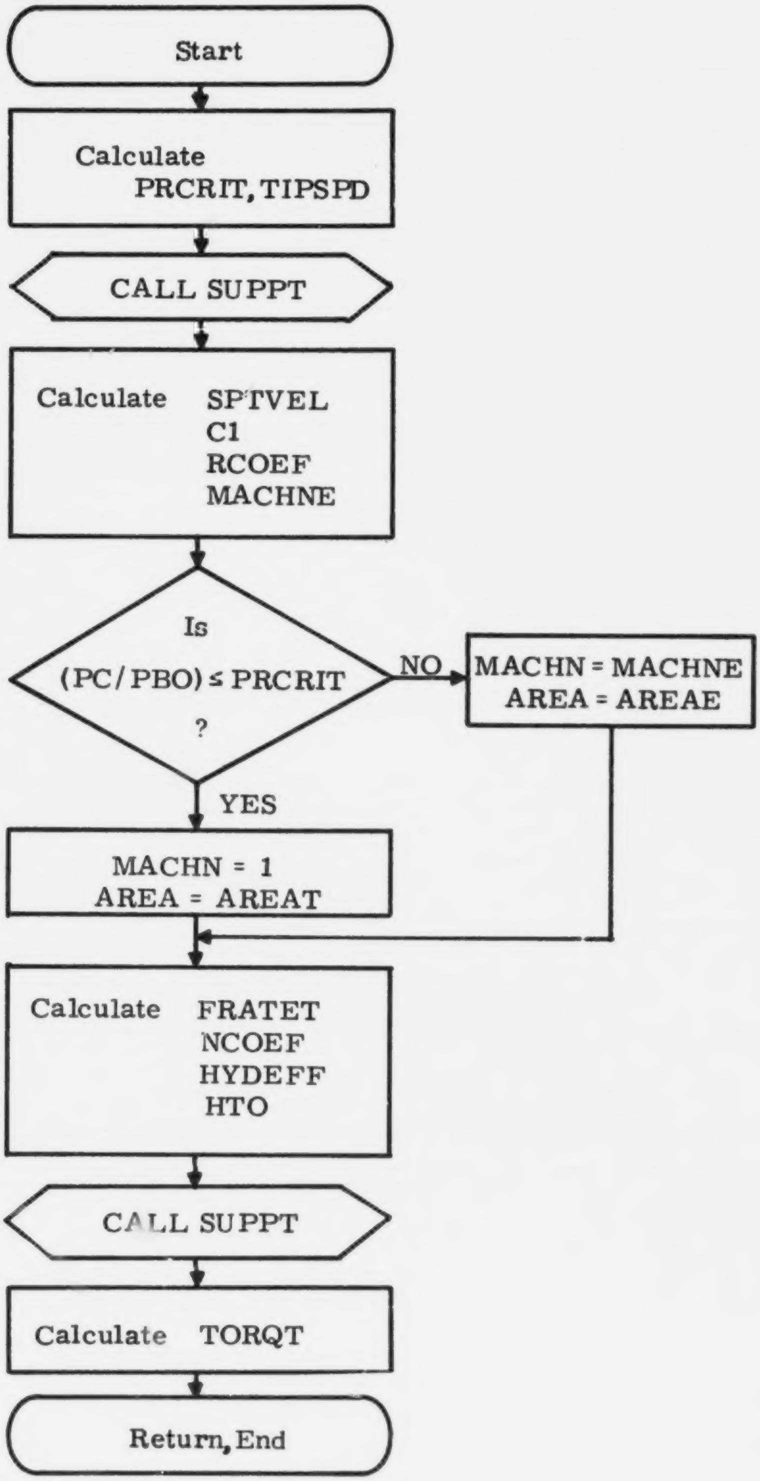
FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
FRATET	Mass flow	lb/sec
HTO	Exit enthalpy	Btu/lb
PBO	Inlet pressure	$lb/in.^2$
PC	Exhaust pressure	$lb/in.^2$
RPMT	Rotational speed	rpm
TBO	Inlet temperature	°F
TEMPTO	Outlet temperature	°F
TORQT	Torque	ft -lb
VOLTO	Outlet specific volume	ft^3/lb

Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
C1	Flow velocity relative to turbine blades	--
HBO	Inlet enthalpy	Btu/lb

FLOW DIAGRAM -- TURBIN


Start
Calculate PRCRIT, TIPSPD
CALL SUPPT
Calculate SPTVEL C1 RCOEF MACHNE
Is (PC/PBO) ≤ PRCRIT ?
NO
MACHN = MACHNE
AREA = AREAE
YES
MACHN = 1
AREA = AREAT
Calculate FRATET NCOEF HYDEFF HTO
CALL SUPPT
Calculate TORQT
Return, End

PROGRAM LISTING -- TURBIN

```
      SUBROUTINE TURBIN(TBO,PBO,PC,RPMT,FRATET,TORQT,TEMPTO,VOLTO,HTO)
      COMMON NND,INO,NPSTEP,NTSTEP,NLINE,P(25),T(25),VLIQ(25),
     1VVAP(25),HLIQ(25),HVAP(25),PTAB(36),TTAB(20),VTAB(35,20),
     2HTAB(35,20),STAB(35,20)
      COMMON GAMMA,ROTDIA,SPTVEL,AREAT,NOZANG,MACHD,NCOFFD,GASC
     1,STO,NCOEFF,MACHN,HYDEFF,TIPSPD,RCOEFF,MACHNE,PRCRIT,AREAE
      REAL MACHNT,NCOFF,MACHNE,MACHN,MACHD,NCOFFD
      PRCRIT=(2./(GAMMA+1.))**(GAMMA/(GAMMA-1.))
      TIPSPD=(RPMT*6.28*ROTDIA)/(2.*60.)
      CALL SUPPT(PBO,TBO,HBO,SBO,VBO,1)
      CALL SUPPT(PC,TEMPTS,HTOS,SBO,VOLTOS,2)
      SPTVEL=(2.*32.2*778.*(HBO-HTOS))**.5
      CV=SPTVEL*COS(NOZANG)
      CT=SPTVEL*SIN(NOZANG)
      WRITE(6,120)PRCRIT,TIPSPD,SPTVEL,CV,CT
      C1=(CT**2+(CV-TIPSPD)**2)**.5
      RCOFF=.99342-2.1698E-04*C1+7.54995E-08*(C1**2)-10.0874E-12*
     1 (C1**3)-9.51861E-16*(C1**4)+26.5401E-20*(C1**5)
      MACHNE=(((PBO/PC)**((GAMMA-1.)/GAMMA)-1.)*(2./(GAMMA-1.)))**.5
      IF((PC/PBO).LE.PRCRIT) GO TO 10
      AREA=AREAE
      MACHN=MACHNE
       GO TO 20
 10   MACHNT=1.
      MACHN=MACHNT
      AREA=AREAT
 20   TEMPAR=TBO+460.0
      FRATET=AREA*(((GAMMA*32.2)/(GASC*TEMPAR))**.5)*
     1 (PBO*MACHN)/(1.+((MACHN**2)*(GAMMA-1.)/2.)**((GAMMA+1.)/
     2 (2.*(GAMMA-1.))))
      RMACH=MACHNE/MACHD
      NCOFF=NCOFFD*(.71806-1.6165*RMACH+1.5039*(RMACH**2)+
     14.9136*(RMACH**3)-6.5855*(RMACH**4)+2.0591*(RMACH**5))
      WRITE(6,120)C1,RCOFF,AREA,RMACH
      IF(NCOFF.GT.1.) WRITE(6,110)
      HYDEFF=(2.*TIPSPD/SPTVEL)*(1.+RCOFF)*(NCOEF*COS(NOZANG)
     1 -(TIPSPD/SPTVEL))
      DELTAH=HYDEFF*(HBO-HTOS)
      HTO=HBO-DELTAH
      CALL SUPPT(PC,TEMPTO,HTO,STO,VOLTO,3)
      TORQT=(DELTAH*FRATET*778.*60.)/(6.28*RPMT)
 110  FORMAT(1H0,33HNOZZLE COEFFICIENT GREATER THAN 1)
 120  FORMAT(5E15.5)
      RETURN
      END
```

Section 5

FEEDPUMP MODEL

MAIN PROGRAM--PUMP

The feedpump model is entitled PUMP. The model employs the subroutine SATP.

NOMENCLATURE -- PUMP

FORTRAN Variables in COMMON:

There is no COMMON block in PUMP.

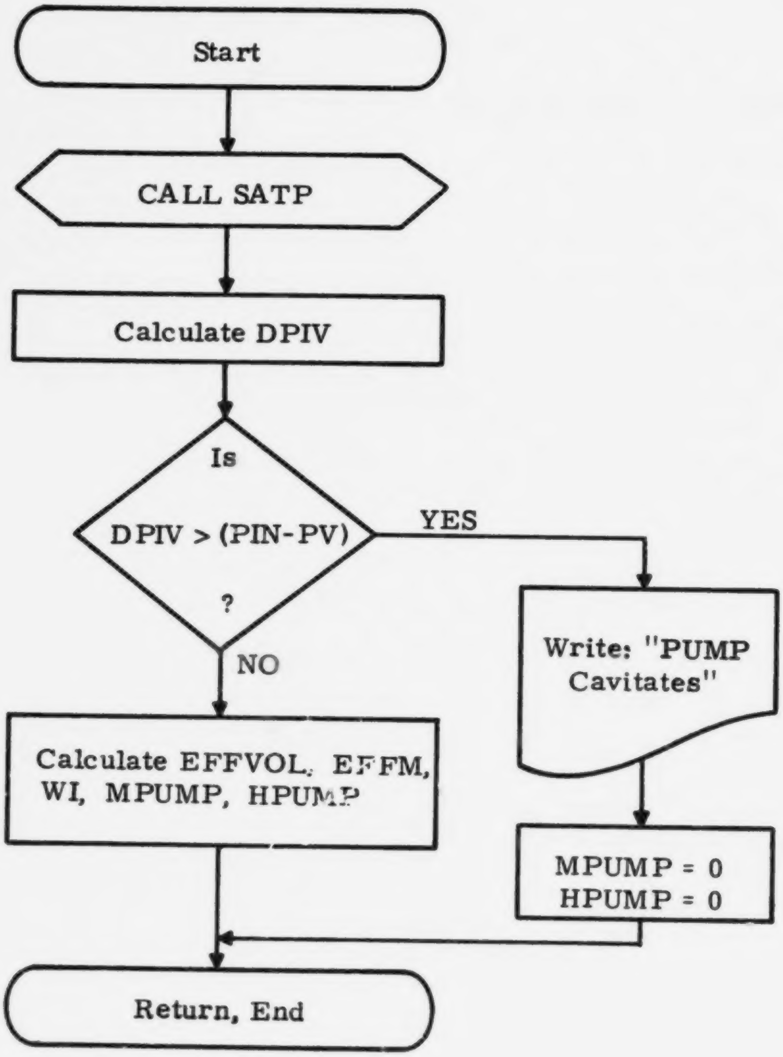
FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
DISP	Maximum displacement	$in.^3$
HPUMP	Pump power	hp
MPUMP	Mass flow rate	lb/sec
NPCYL	Number of cylinders	--
PIN	Inlet pressure	$lb/in.^2$
POUT	Exit pressure	$lb/in.^2$
RPM	Rotational speed	rpm
RPUMP	Variable displacement ratio	--
TIN	Inlet temperature	°F

Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
DPIV	Pressure drop across inlet valve	psi
EFFM	Mechanical efficiency	--
EFFVOL	Volumetric efficiency	--
VL	Specific volume	ft^3/lb
WI	Flow work	Btu/lb

FLOW DIAGRAM -- PUMP


Start
CALL SATP
Calculate DPIV
Is
DPIV > (PIN-PV)
?
YES
NO
Write: "PUMP Cavitates"
Calculate EFFVOL, EFFM, WI, MPUMP, HPUMP
MPUMP = 0
HPUMP = 0
Return, End

PROGRAM LISTING -- PUMP

```
      SUBROUTINE PUMP(RPUMP,RPM,PIN,POUT,TIN,MPUMP,HPUMP,
     7DISP,NPCYL)
      REAL MPUMP
      CALL SATP(PV,TIN,VL,VV,HL,HV,0)
      DPIV=((RPUMP*DISP/FLOAT(NPCYL))**2)*(RPM)**2/((3300.)**2*VL)
      IF(DPIV.GT.(PIN-PV)) GO TO 100
      EFFVOL=1.-.05*(RPM/600.)
      EFFM=1./(1.+115./(EFFVOL*(POUT-PIN)))
      WI=VL*(POUT-PIN)*(144./778.)
      MPUMP=(RPUMP*DISP*RPM*EFFVOL)/(VL*1728.*60.)
      HPUMP=(WI*MPUMP*3600.*3.29E-4)/EFFM
      GO TO 200
100   WRITE(6,210)
210   FORMAT(15H PUMP CAVITATES)
      WRITE(6,220) DPIV,PIN,PV
220   FORMAT(14H DPIV,PIN,PV  ,3F15.5)
      MPUMP=0.
      HPUMP=0.
200   RETURN
      END
```

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Section 6

VAPOR GENERATOR MODEL

Section 6

VAPOR GENERATOR MODEL

MAIN PROGRAM--VAPORG

The vapor generator model is entitled VAPORG. The model employs the following subroutines:

DISTR
GEOMCO
STEPSI
ITERAT
SATP
PROP
SUPPT
PROPST
PDROP1
PDROP2
PDROPA
INTSTE
PHASE
HT1PB
HT2PB
HTGR
HTGTB
HTGTF
HTGTM
HTPF
FCWL
FDWL
FKWL
FVWL
FYWL
FCWV
FDWV
FKWV
FVWV
FCA
FDA
FKA
FCG
FDG
FKG
FVG
FCMC
FKC
FRMC
FCMS
FKS
FRMS
FKM
FVA

Figure 1 illustrates the links between the various subroutines required for VAPORG.

The input parameter, FRAC, is the ratio of actual step size to stability step size. To avoid numerical instability, its value should be less than unity. FRAC has been set at 0.5 in the present program.

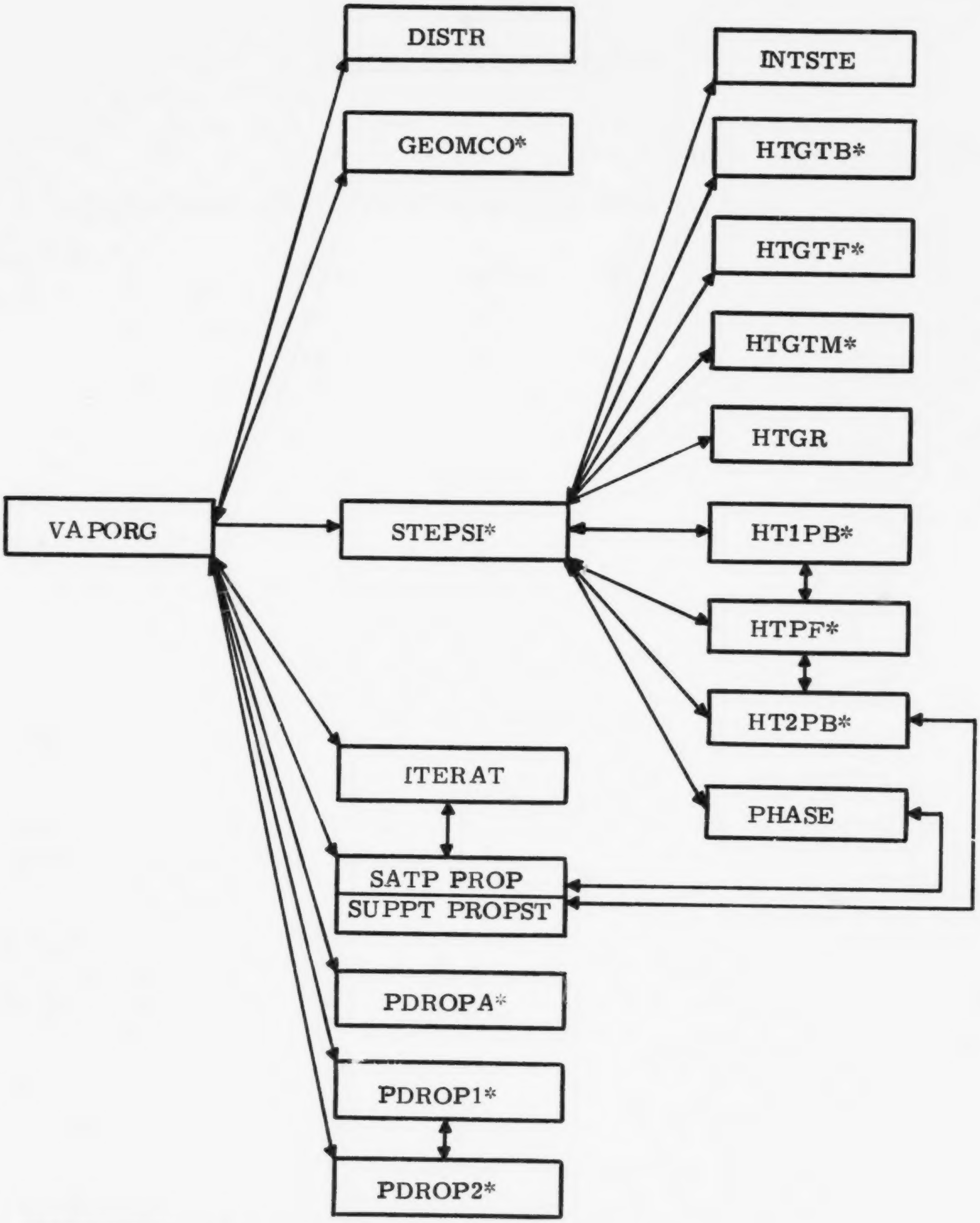
The data file referenced in VAPORG by the two-digit code 13 is a storage file for values output at the completion of the VAPORG run. The user can then employ this file as the input file, code 11, for a transient start run. Since the data in the file vary according to the particular run just completed, a listing is not included here.

NOMENCLATURE -- VAPORG

FORTRAN Variables in COMMON:

FORTRAN variables in the COMMON of VAPORG are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:


DISTR
GEOMCO*
INTSTE
HTGTB*
HTGTF*
HTGTM*
HTGR
VAPORG
STEPSI*
HT1PB*
HTPF*
HT2PB*
PHASE
ITERAT
SATP PROP
SUPPT PROPST
PDROPA*
PDROP1*
PDROP2*

---

*These subroutines use fluid or metal properties.

Figure 1. Links Between Subroutines Used by VAPORG

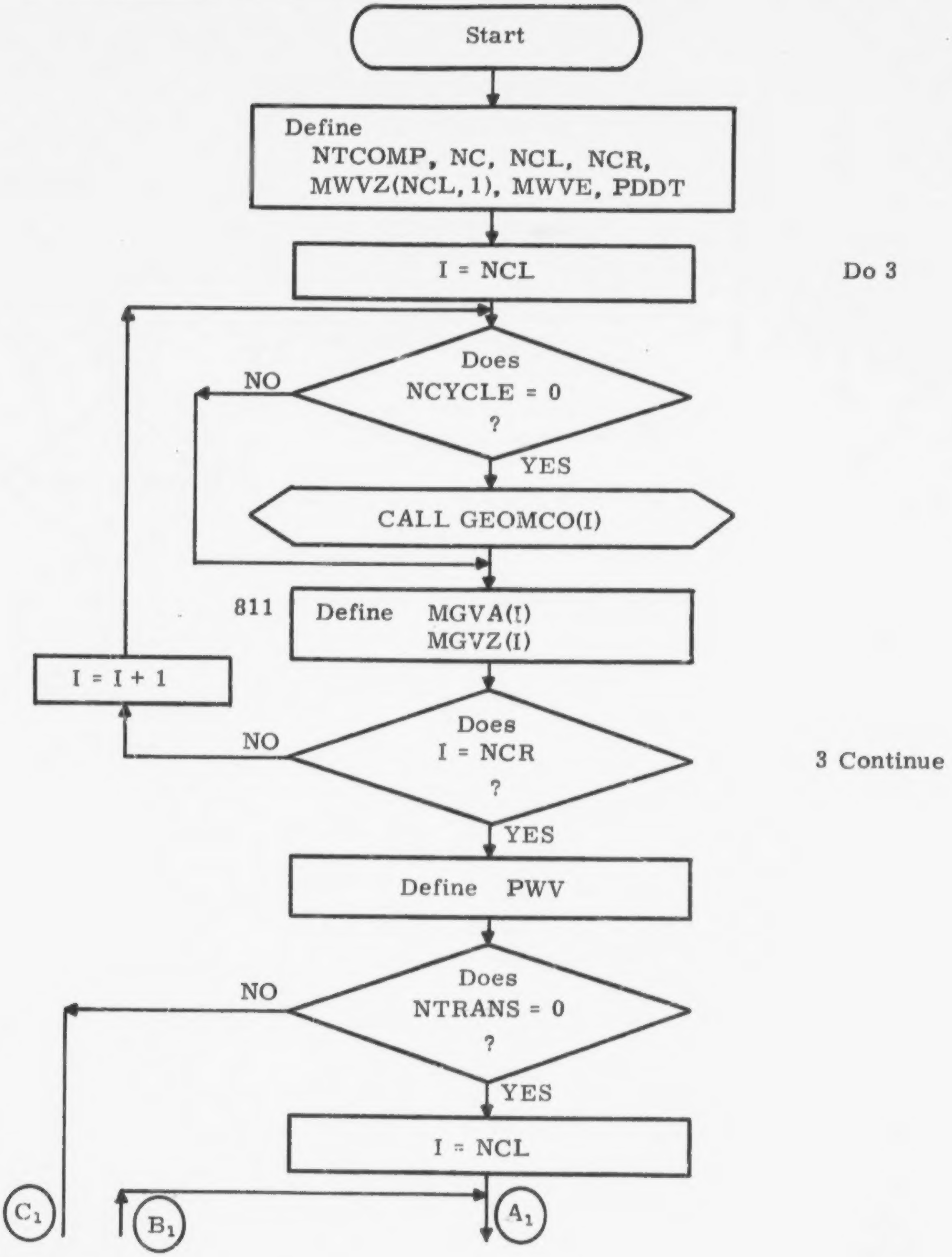
FORTRAN Variable	Definition	Units
JS	Variable to denote cumulative number of timesteps	--
MGI	Mass flow rate of gas at inlet	lb/sec
MWE	Mass flow rate of working fluid at exit	lb/sec
NST	Logic variable for transient start 0 - steady-state case 1 - transient case	--
PGVE	Pressure of gas at exit	$lb/in.^2$
PGVI	Pressure of gas at inlet	$lb/in.^2$
PWVE	Pressure of working fluid at exit	$lb/in.^2$
PWVI	Pressure of working fluid at inlet	$lb/in.^2$
TGVI	Temperature of gas at inlet	°F

Other Selected FORTRAN Variables:

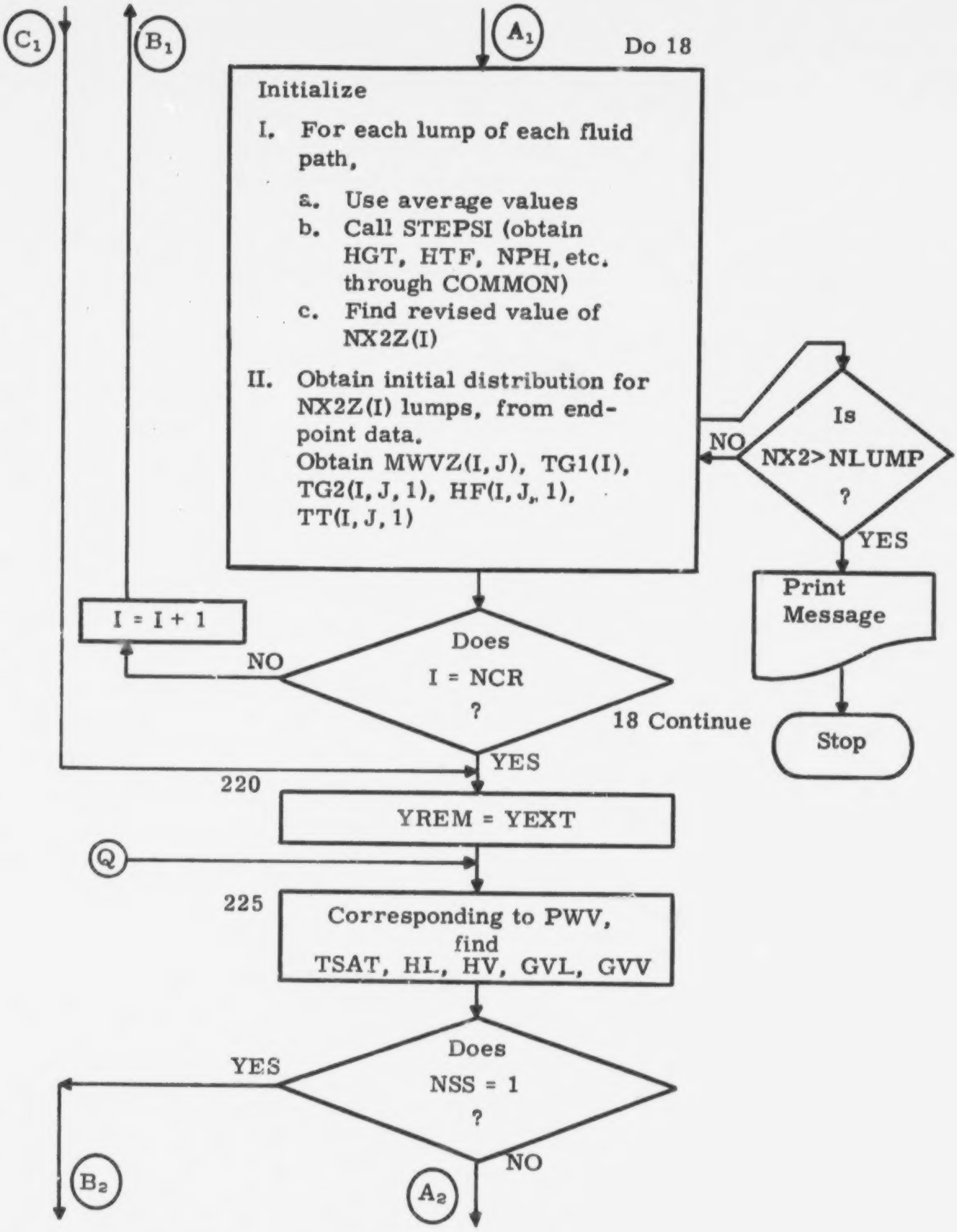
FORTRAN Variable	Definition	Units
CPP	Specific heat of fluid	Btu/lb -°F
DXN	Stability distance limit, at future time	in.
DXO	Stability distance limit, at present time	in.
DYY	Selected time step	sec
FCON	Parameter for dynamic relations -- tube	°F
FF2F1	Parameter for dynamic relations -- fluid	--
FF2F2	Parameter for dynamic relations -- fluid	--
FF2T	Parameter for dynamic relations -- fluid	Btu/lb °F
FG2G1	Parameter for dynamic relations -- gas	--
FG2T	Parameter for dynamic relations -- gas	--
FTF	Parameter for dynamic relations -- tube	lb-°F/Btu

FORTRAN Variable	Definition	Units
FTG	Parameter for dynamic relations -- tube	--
FTT	Parameter for dynamic relations -- tube	--
LZ	Tube length for particular fluid phase	in.
MGVZ(I)	Gas mass flow rate for fluid pass I	lb/sec
MWVZ(I, J)	Fluid mass flow rate for fluid pass I at node J	lb/sec
NBB	Required number of iterations for gas side energy transient	--
NITER	Required number of subdivisions for continuity equation	--
PINCT	Fluid pressure change during time step DYY	lb/in.^{2}
PWV	Fluid pressure	lb/in.^{2}
QTOT	Total energy transfer	Btu/sec
RO	Fluid density	lb/ft^3
VAL	System volume	in.^{3}
VAL1	Total fluid volume occupied by subcooled phase	in.^{3}
VAL2	Total fluid volume occupied by boiling phase	in.^{3}
VAL3	Total fluid volume occupied by superheat phase	in.^{3}
WF	Captive saturated liquid mass	lb
WG	Captive saturated vapor mass	lb
WS	Captive superheat fluid mass	lb
XAV1	Average fluid quality	--
XE1	Fluid quality at exit	--
YREM	Time left to reach YEXT	sec

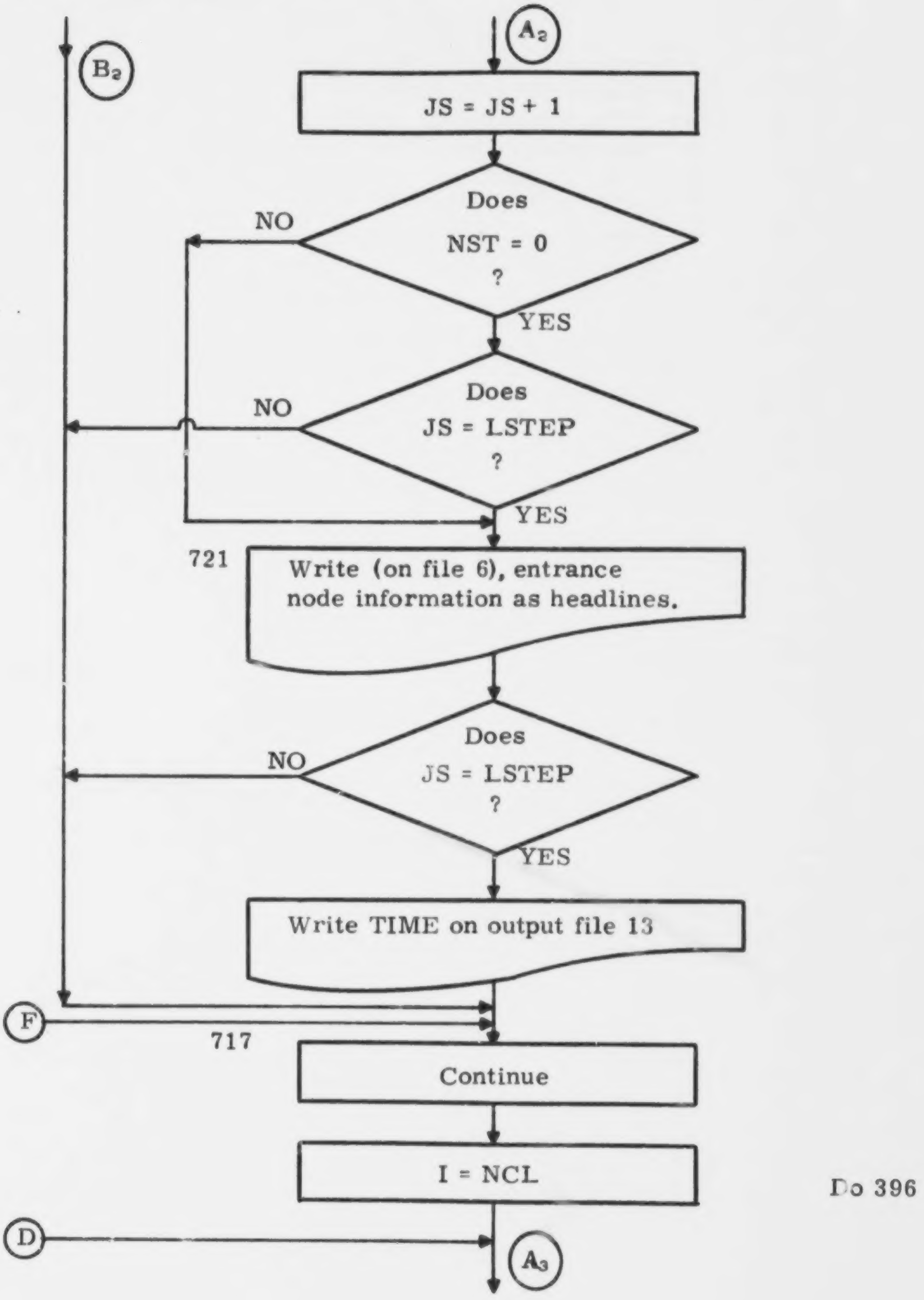
FLOW DIAGRAM -- VAPORG


Start
Define
NTCOMP, NC, NCL, NCR,
MWVZ(NCL, 1), MWVE, PDDT
I = NCL
Do 3
Does
NCYCLE = 0
?
NO
YES
CALL GEOMCO(I)
811
Define MGVA(I)
MGVZ(I)
I = I + 1
Does
I = NCR
?
NO
3 Continue
YES
Define PWV
Does
NTRANS = 0
?
NO
YES
I = NCL
C_1
B_1
A_1

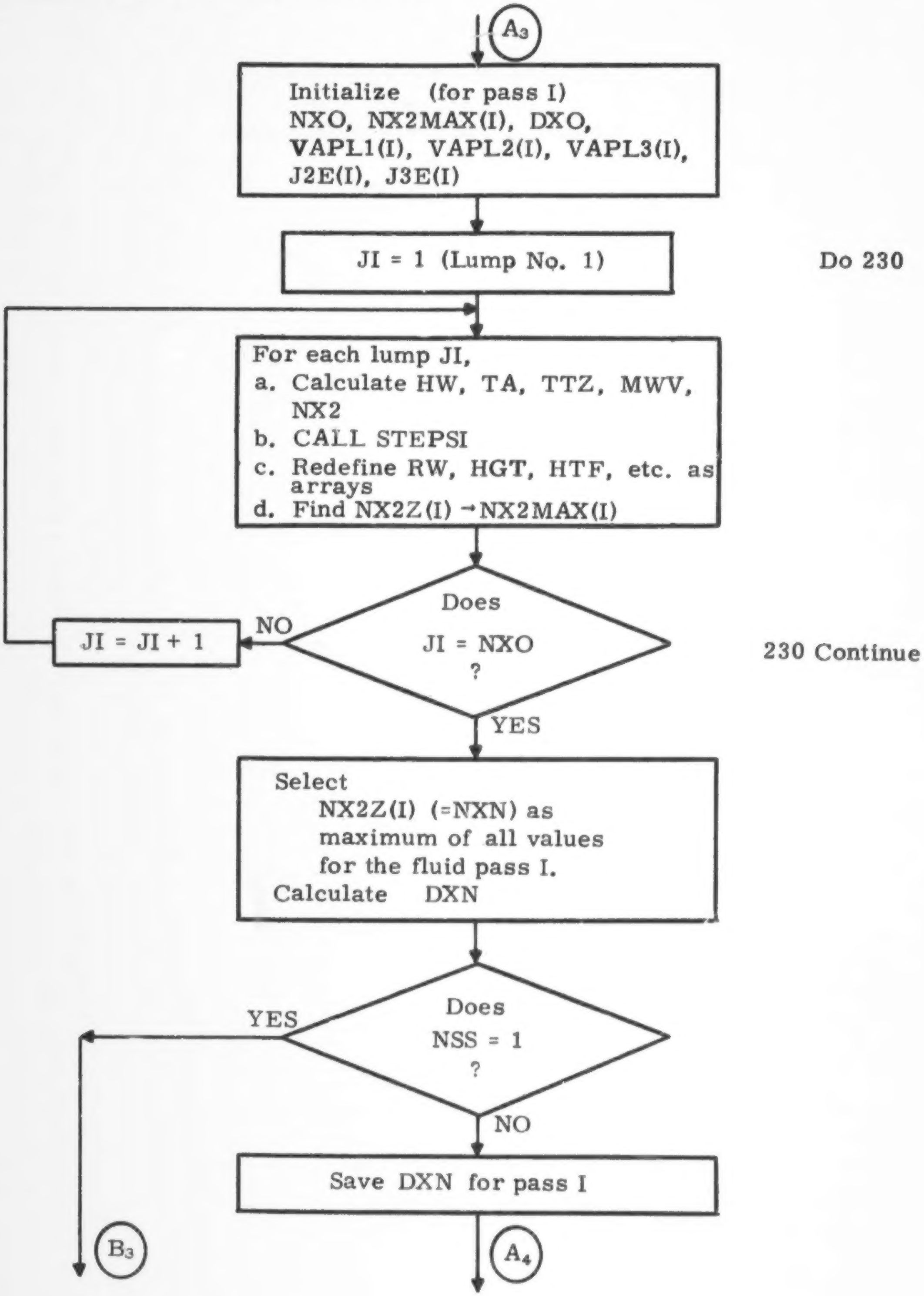
FLOW DIAGRAM -- VAPORG (Cont'd)


C1
B1
A1
Do 18
Initialize
I. For each lump of each fluid path,
a. Use average values
b. Call STEPSI (obtain HGT, HTF, NPH, etc. through COMMON)
c. Find revised value of NX2Z(I)
II. Obtain initial distribution for NX2Z(I) lumps, from end-point data.
Obtain MWVZ(I, J), TG1(I), TG2(I, J, 1), HF(I, J, 1), TT(I, J, 1)
Is NX2>NLUMP ?
NO
YES
Print Message
Stop
I = I + 1
NO
Does I = NCR ?
18 Continue
YES
220
YREM = YEXT
Q
225
Corresponding to PWV, find TSAT, HL, HV, GVL, GVV
Does NSS = 1 ?
YES
NO
B2
A2

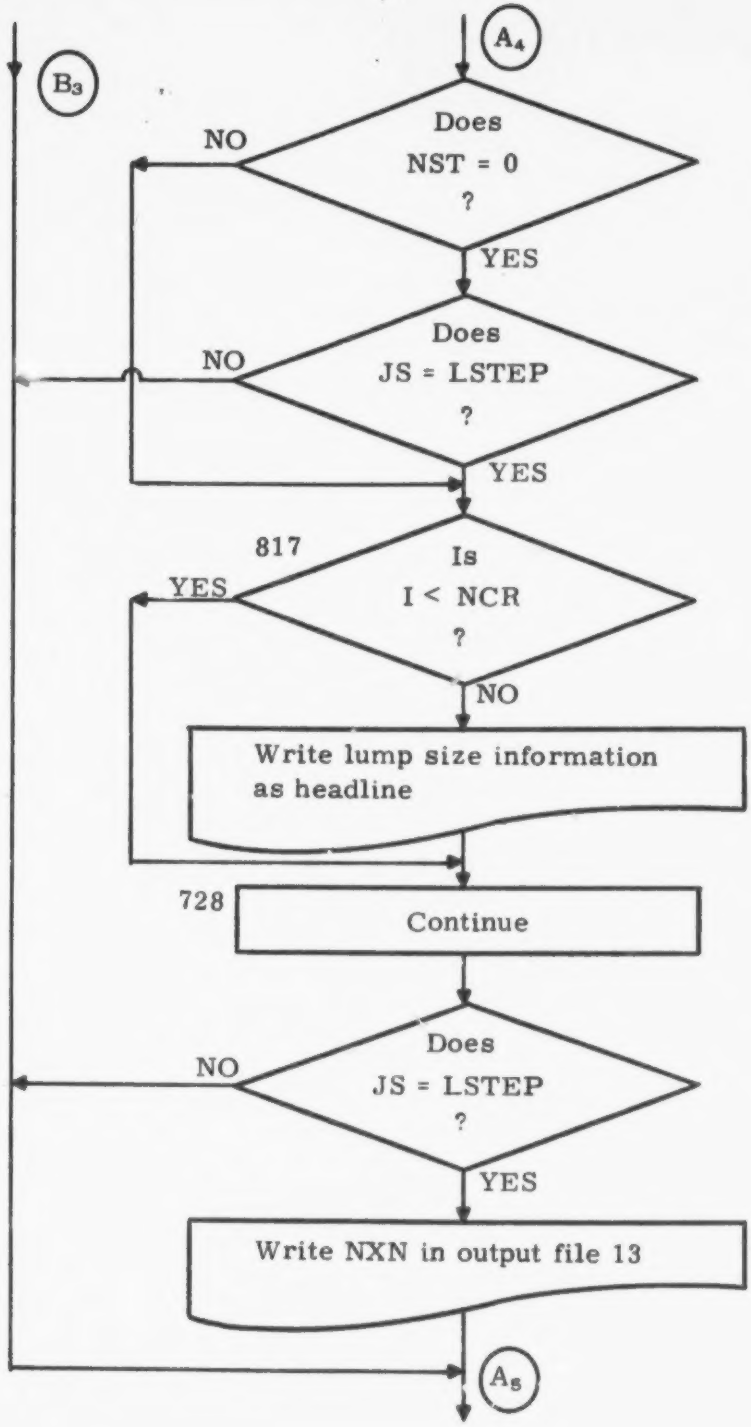
FLOW DIAGRAM -- VAPORG (Cont'd)


A₂
B₂
JS = JS + 1
Does
NST = 0
?
NO
YES
Does
JS = LSTEP
?
NO
YES
721
Write (on file 6), entrance node information as headlines.
Does
JS = LSTEP
?
NO
YES
Write TIME on output file 13
F
717
Continue
I = NCL
Do 396
D
A₃

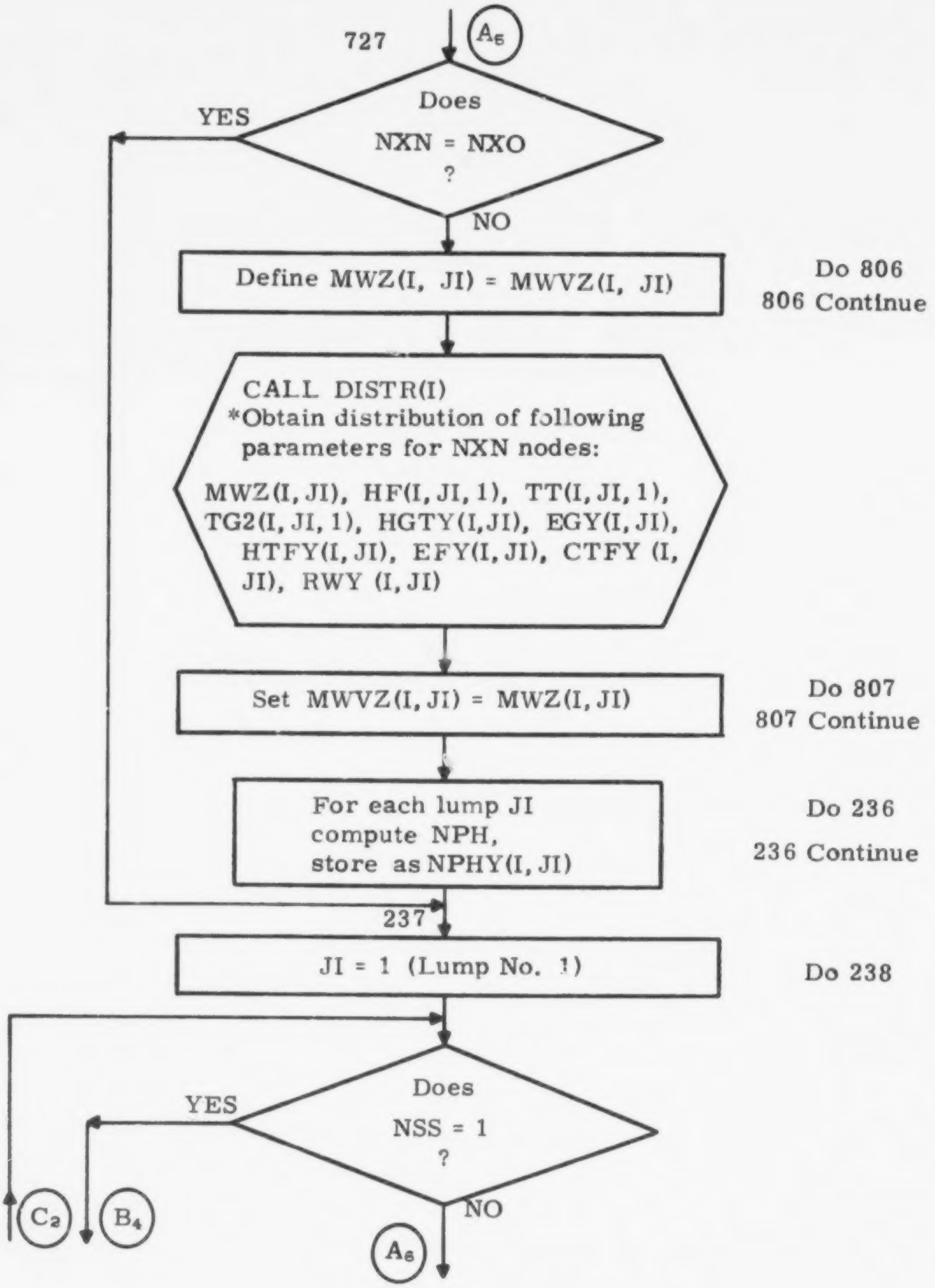
FLOW DIAGRAM -- VAPORG (Cont'd)


A3
Initialize (for pass I)
NXO, NX2MAX(I), DXO,
VAPL1(I), VAPL2(I), VAPL3(I),
J2E(I), J3E(I)
JI = 1 (Lump No. 1)
Do 230
For each lump JI,
a. Calculate HW, TA, TTZ, MWV, NX2
b. CALL STEPSI
c. Redefine RW, HGT, HTF, etc. as arrays
d. Find NX2Z(I) → NX2MAX(I)
Does JI = NXO ?
NO
JI = JI + 1
230 Continue
YES
Select NX2Z(I) (=NXN) as maximum of all values for the fluid pass I.
Calculate DXN
Does NSS = 1 ?
YES
NO
Save DXN for pass I
B3
A4

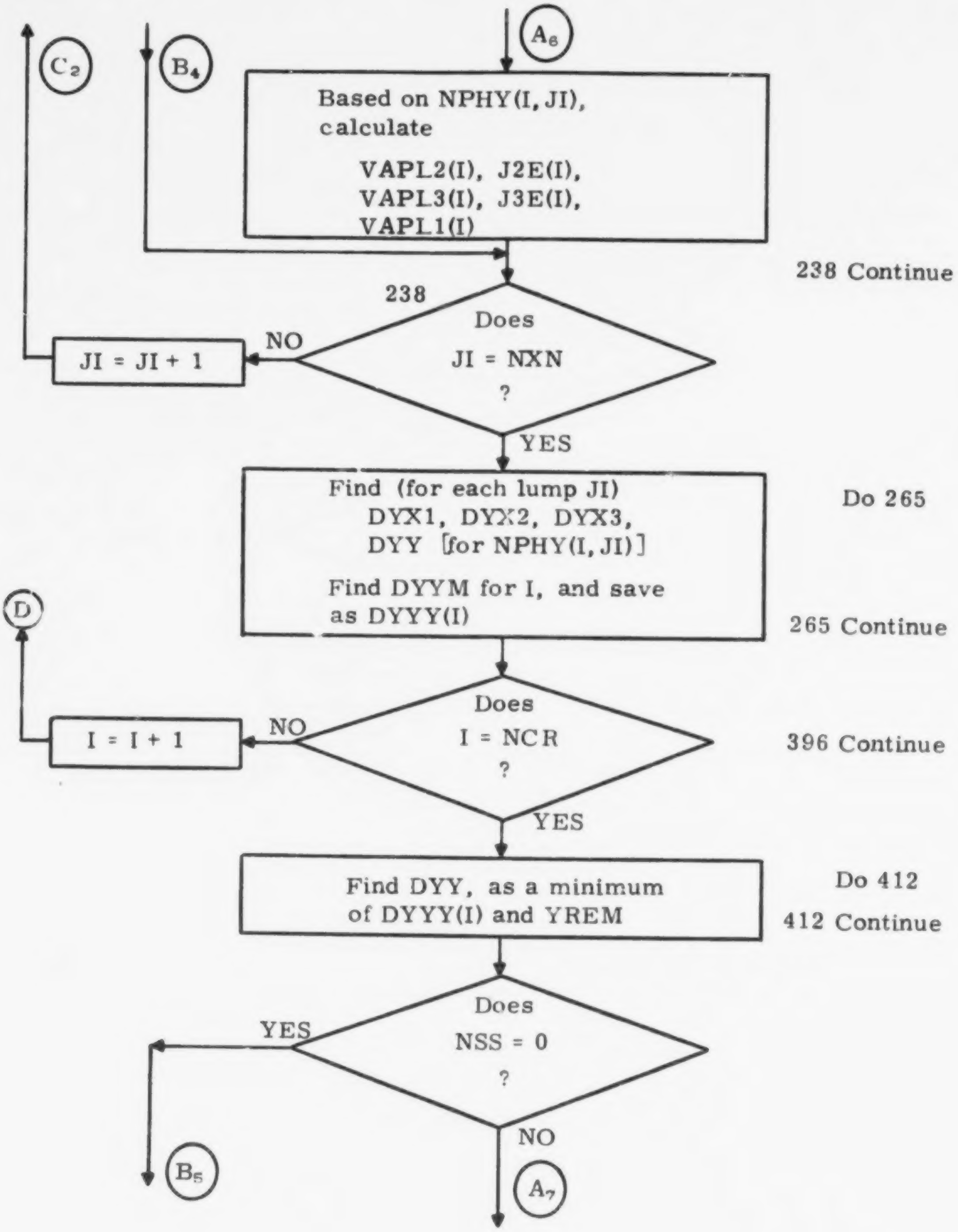
FLOW DIAGRAM -- VAPORG (Cont'd)


A₄
B₃
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
817
Is I < NCR ?
YES
NO
Write lump size information as headline
728
Continue
Does JS = LSTEP ?
NO
YES
Write NXN in output file 13
A₅

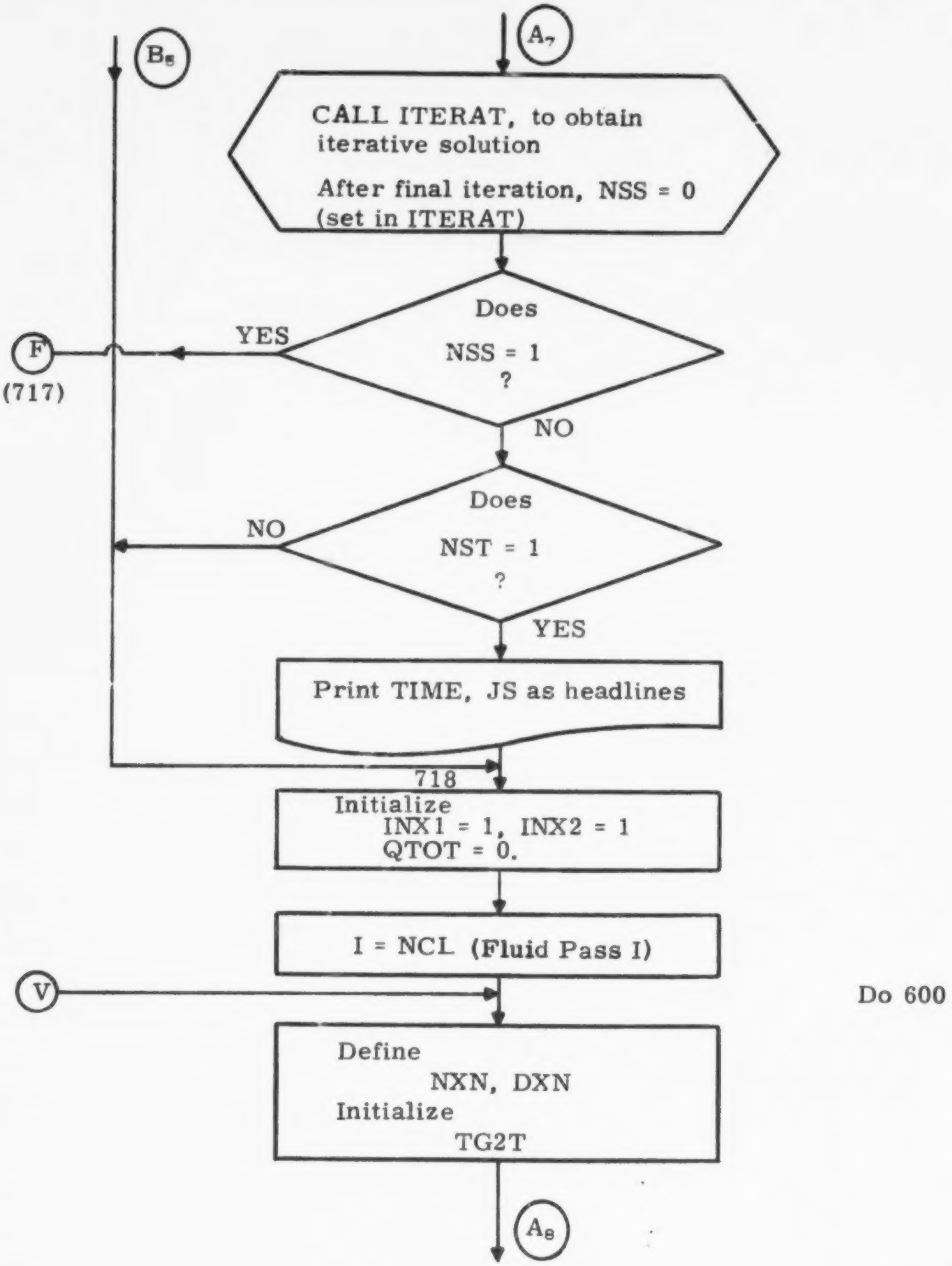
FLOW DIAGRAM -- VAPORG (Cont'd)


727
A_6
Does
NXN = NXO
?
YES
NO
Define MWZ(I, JI) = MWVZ(I, JI)
Do 806
806 Continue
CALL DISTR(I)
*Obtain distribution of following parameters for NXN nodes:
MWZ(I, JI), HF(I, JI, 1), TT(I, JI, 1), TG2(I, JI, 1), HGTY(I,JI), EGY(I, JI), HTFY(I, JI), EFY(I, JI), CTFY (I, JI), RWY (I, JI)
Set MWVZ(I, JI) = MWZ(I, JI)
Do 807
807 Continue
For each lump JI
compute NPH,
store as NPHY(I, JI)
Do 236
236 Continue
237
JI = 1 (Lump No. 1)
Do 238
Does
NSS = 1
?
YES
NO
C_2
B_4
A_6

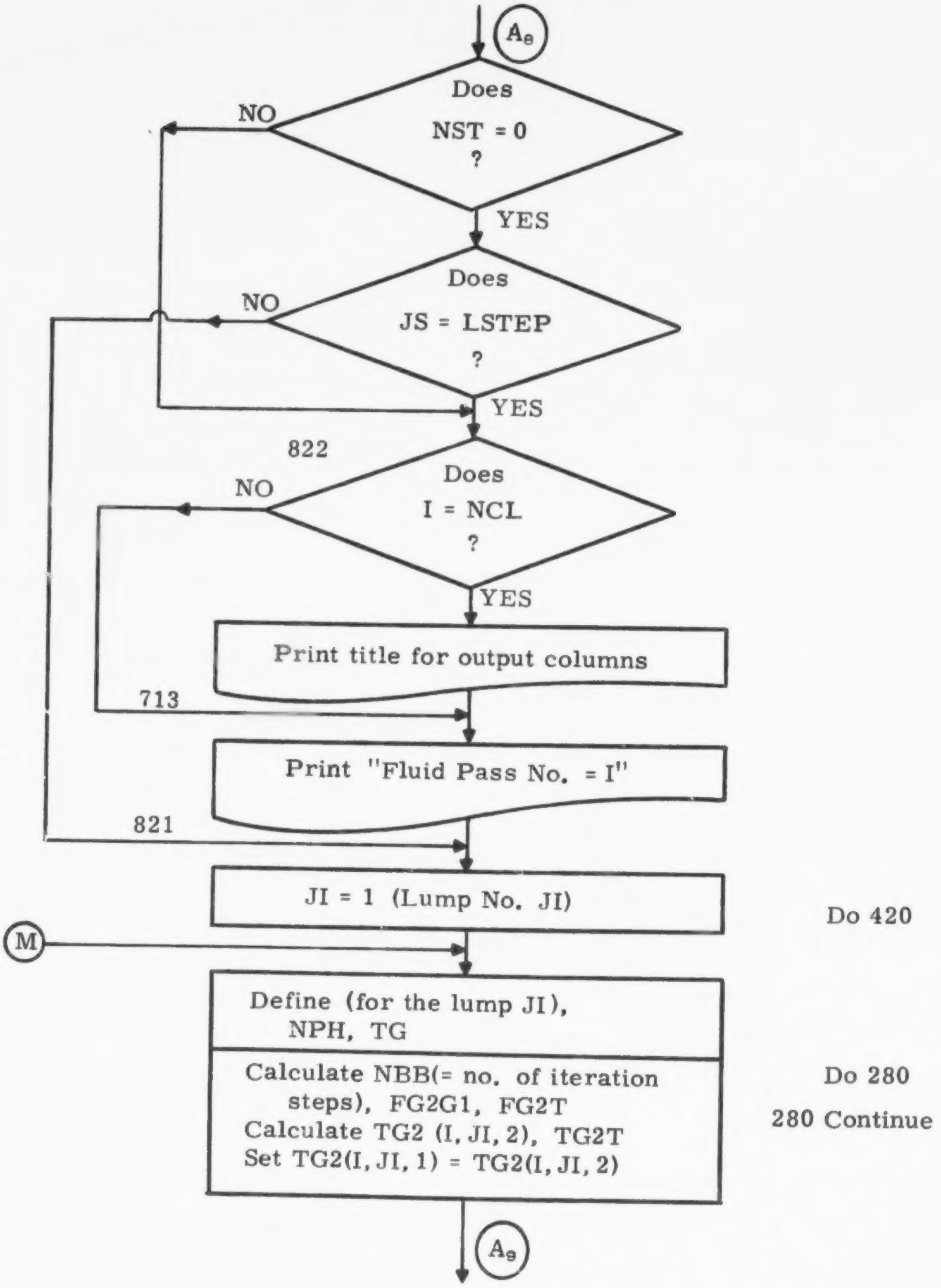
FLOW DIAGRAM -- VAPORG (Cont'd)


C₂
B₄
A₆
Based on NPHY(I, JI), calculate
VAPL2(I), J2E(I),
VAPL3(I), J3E(I),
VAPL1(I)
238 Continue
238
Does JI = NXN ?
NO
JI = JI + 1
YES
Find (for each lump JI)
DYX1, DYX2, DYX3,
DYY [for NPHY(I, JI)]
Find DYYM for I, and save as DYYY(I)
Do 265
265 Continue
D
Does I = NCR ?
NO
I = I + 1
396 Continue
YES
Find DYY, as a minimum of DYYY(I) and YREM
Do 412
412 Continue
Does NSS = 0 ?
YES
NO
B₅
A₇

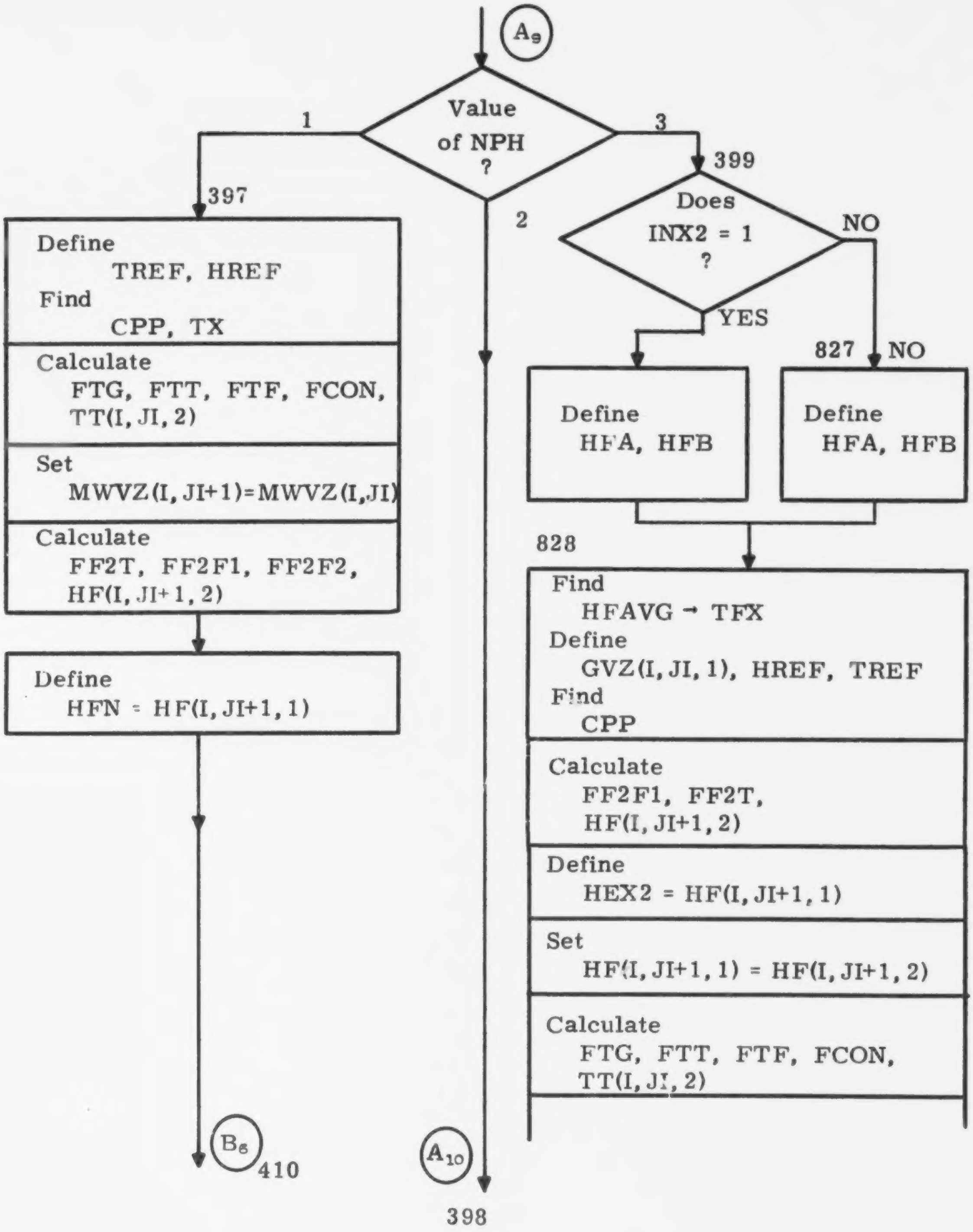
FLOW DIAGRAM -- VAPORG (Cont'd)


A₇
B₅
CALL ITERAT, to obtain iterative solution
After final iteration, NSS = 0 (set in ITERAT)
Does NSS = 1 ?
YES
F
(717)
NO
Does NST = 1 ?
NO
YES
Print TIME, JS as headlines
718
Initialize
INX1 = 1, INX2 = 1
QTOT = 0.
I = NCL (Fluid Pass I)
V
Do 600
Define
NXN, DXN
Initialize
TG2T
A₈

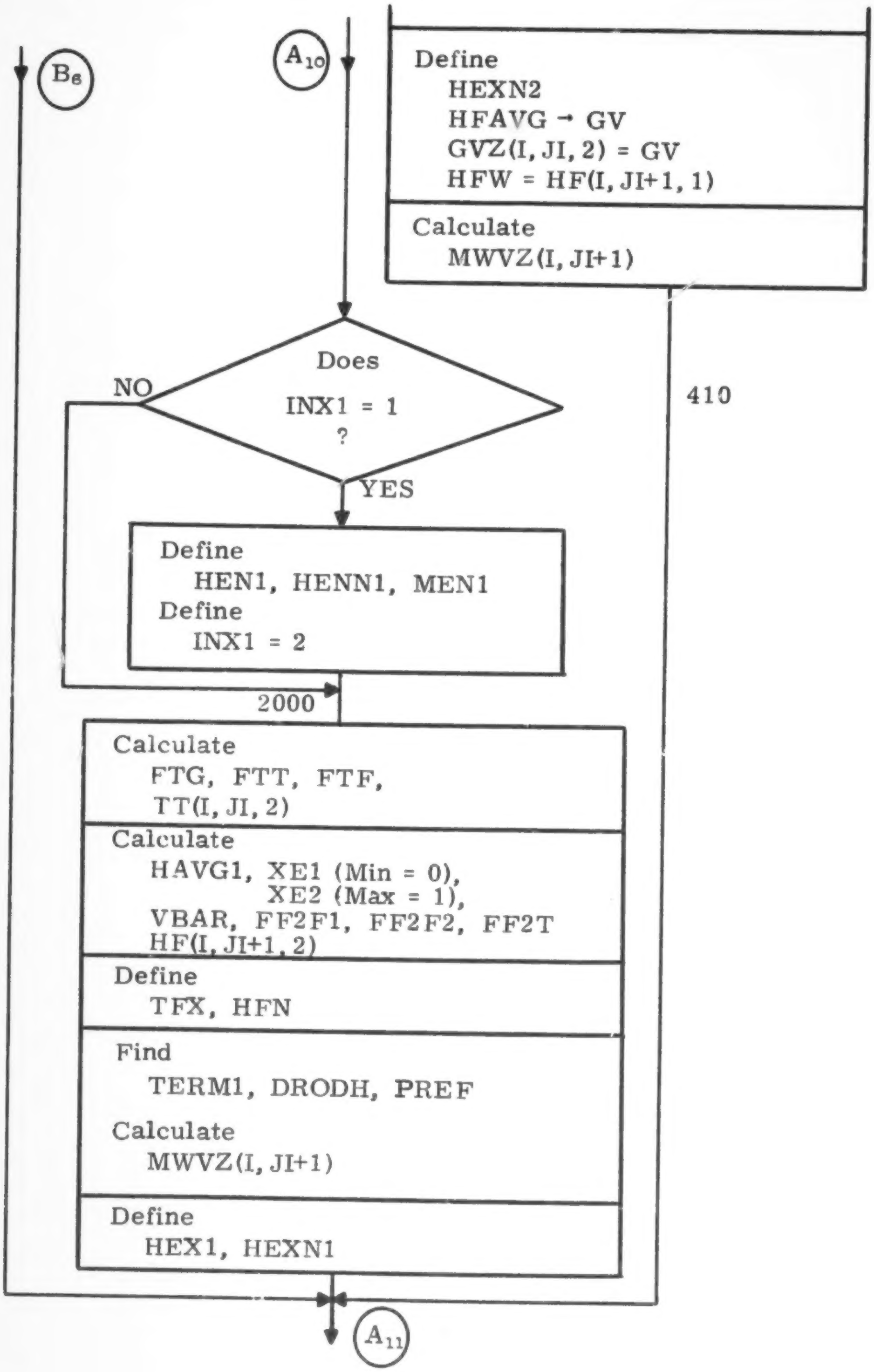
FLOW DIAGRAM -- VAPORG (Cont'd)


A8
Does
NST = 0
?
NO
YES
Does
JS = LSTEP
?
NO
YES
822
Does
I = NCL
?
NO
YES
Print title for output columns
713
Print "Fluid Pass No. = I"
821
JI = 1 (Lump No. JI)
Do 420
M
Define (for the lump JI),
NPH, TG
Calculate NBB(= no. of iteration steps), FG2G1, FG2T
Calculate TG2 (I, JI, 2), TG2T
Set TG2(I, JI, 1) = TG2(I, JI, 2)
Do 280
280 Continue
A9

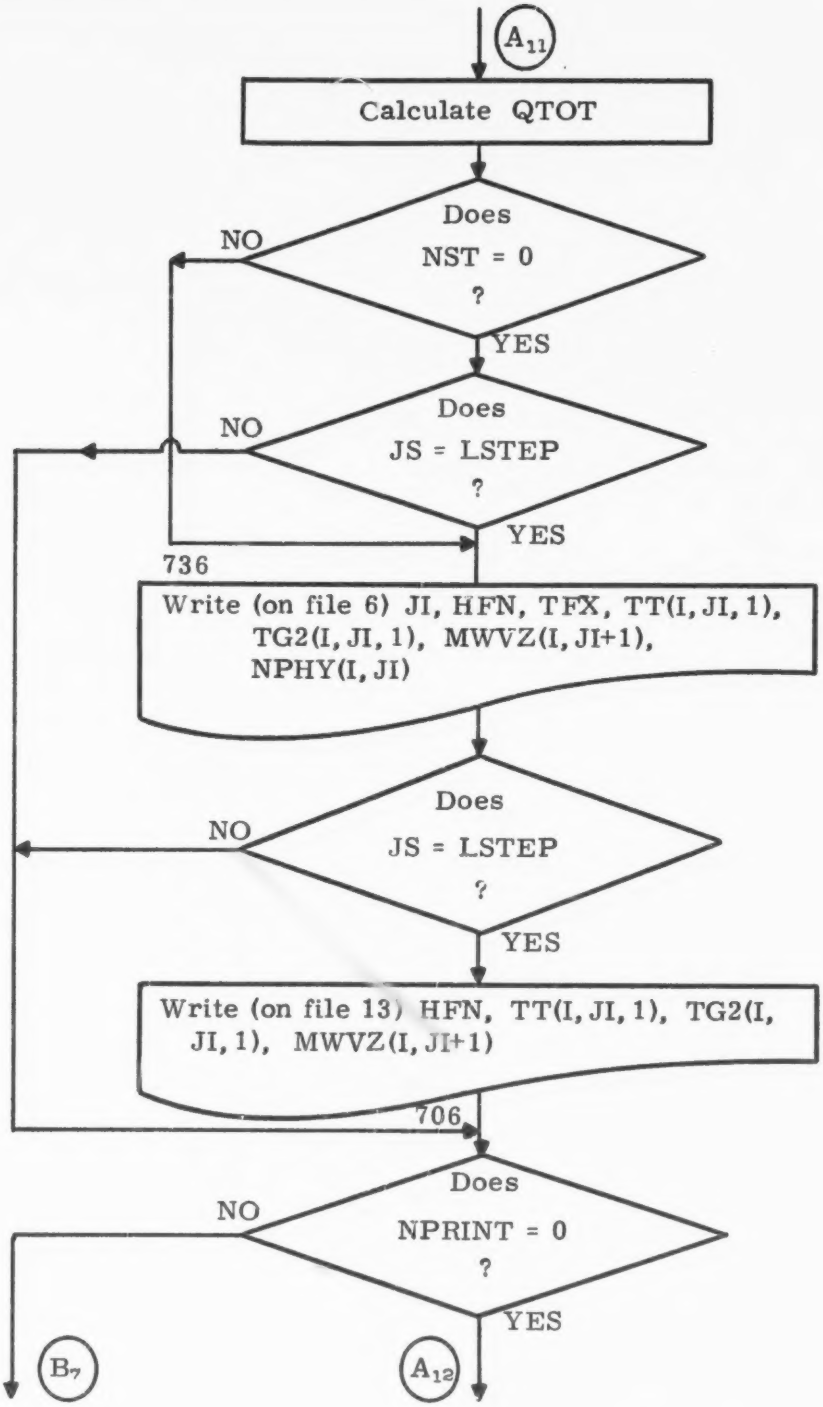
FLOW DIAGRAM -- VAPORG (Cont'd)


A9
Value of NPH ?
1
3
2
399
Does INX2 = 1 ?
NO
YES
397
Define TREF, HREF
Find CPP, TX
Calculate FTG, FTT, FTF, FCON, TT(I, JI, 2)
Set MWVZ(I, JI+1)=MWVZ(I,JI)
Calculate FF2T, FF2F1, FF2F2, HF(I, JI+1, 2)
Define HFN = HF(I, JI+1, 1)
827
NO
Define HFA, HFB
Define HFA, HFB
828
Find HFAVG → TFX
Define GVZ(I, JI, 1), HREF, TREF
Find CPP
Calculate FF2F1, FF2T, HF(I, JI+1, 2)
Define HEX2 = HF(I, JI+1, 1)
Set HF(I, JI+1, 1) = HF(I, JI+1, 2)
Calculate FTG, FTT, FTF, FCON, TT(I, JI, 2)
B8
410
A10
398

FLOW DIAGRAM -- VAPORG (Cont'd)

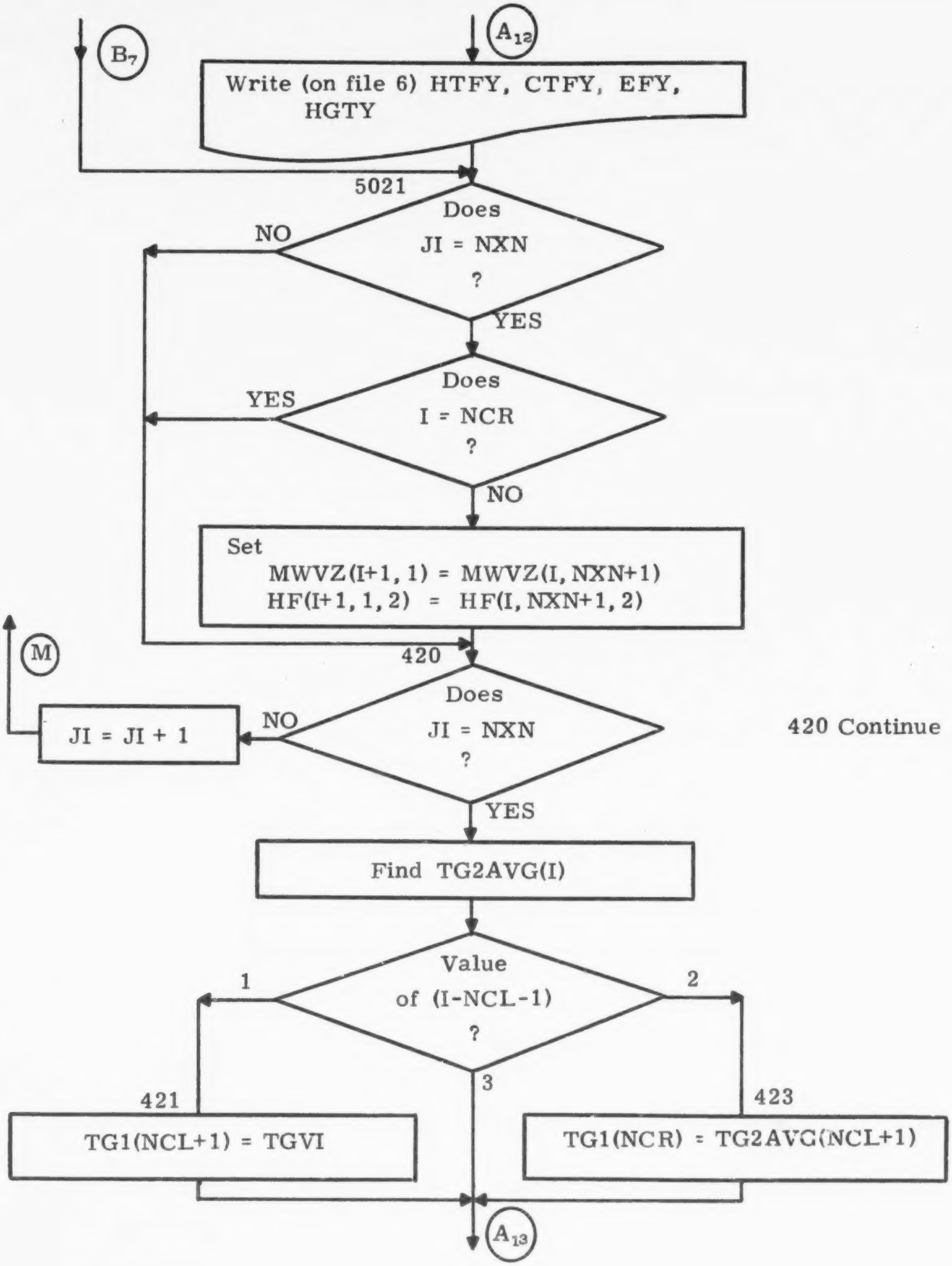

B8
A10
Define
HEXN2
HFAVG → GV
GVZ(I, JI, 2) = GV
HFW = HF(I, JI+1, 1)
Calculate
MWVZ(I, JI+1)
410
Does
INX1 = 1
?
NO
YES
Define
HEN1, HENN1, MEN1
Define
INX1 = 2
2000
Calculate
FTG, FTT, FTF,
TT(I, JI, 2)
Calculate
HAVG1, XE1 (Min = 0),
XE2 (Max = 1),
VBAR, FF2F1, FF2F2, FF2T
HF(I, JI+1, 2)
Define
TFX, HFN
Find
TERM1, DRODH, PREF
Calculate
MWVZ(I, JI+1)
Define
HEX1, HEXN1
A11

FLOW DIAGRAM -- VAPORG (Cont'd)

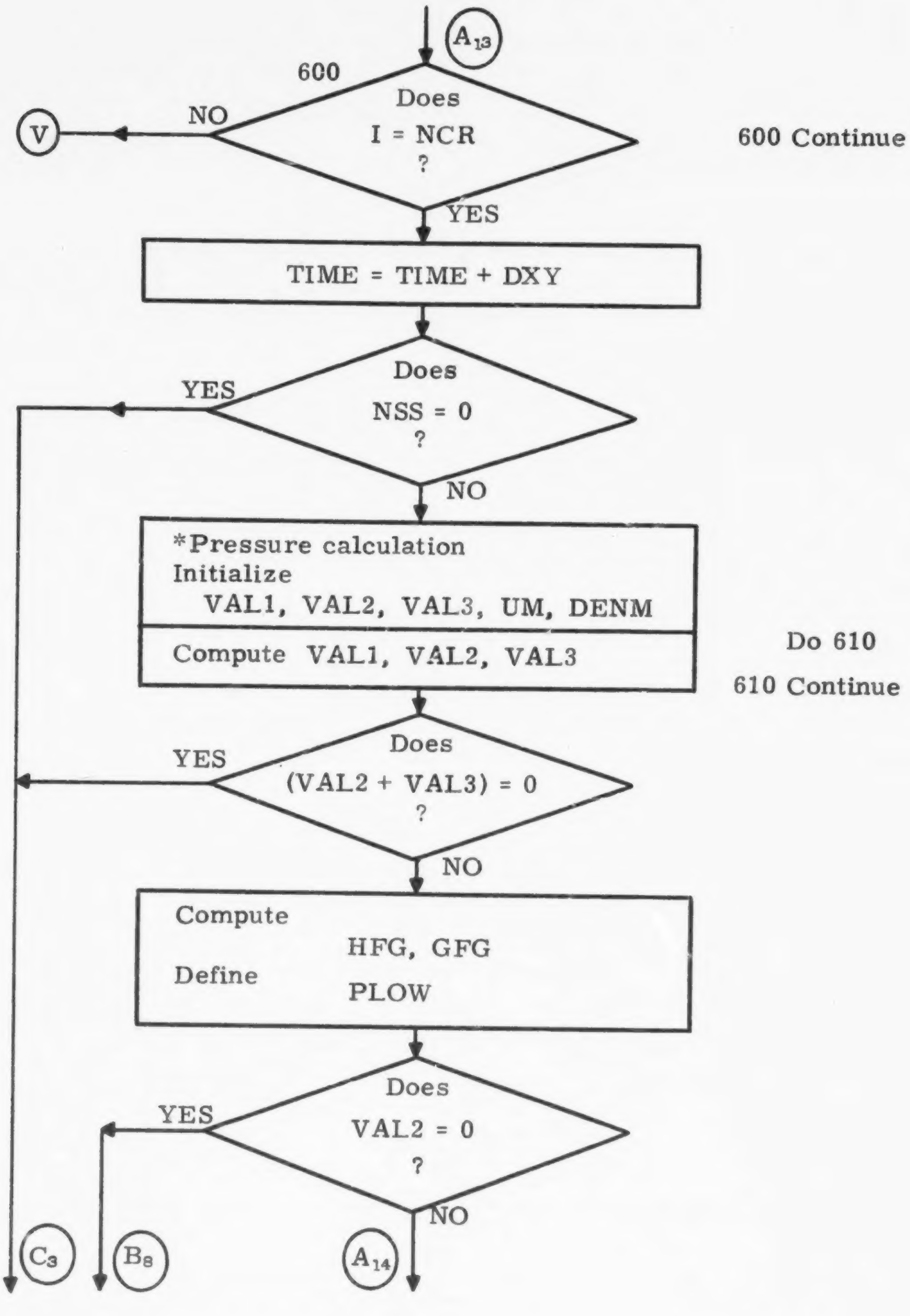


A_{11}
Calculate QTOT
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
736
Write (on file 6) JI, HFN, TFX, TT(I, JI, 1), TG2(I, JI, 1), MWVZ(I, JI+1), NPHY(I, JI)
Does JS = LSTEP ?
NO
YES
Write (on file 13) HFN, TT(I, JI, 1), TG2(I, JI, 1), MWVZ(I, JI+1)
706
Does NPRINT = 0 ?
NO
YES
B_7
A_{12}

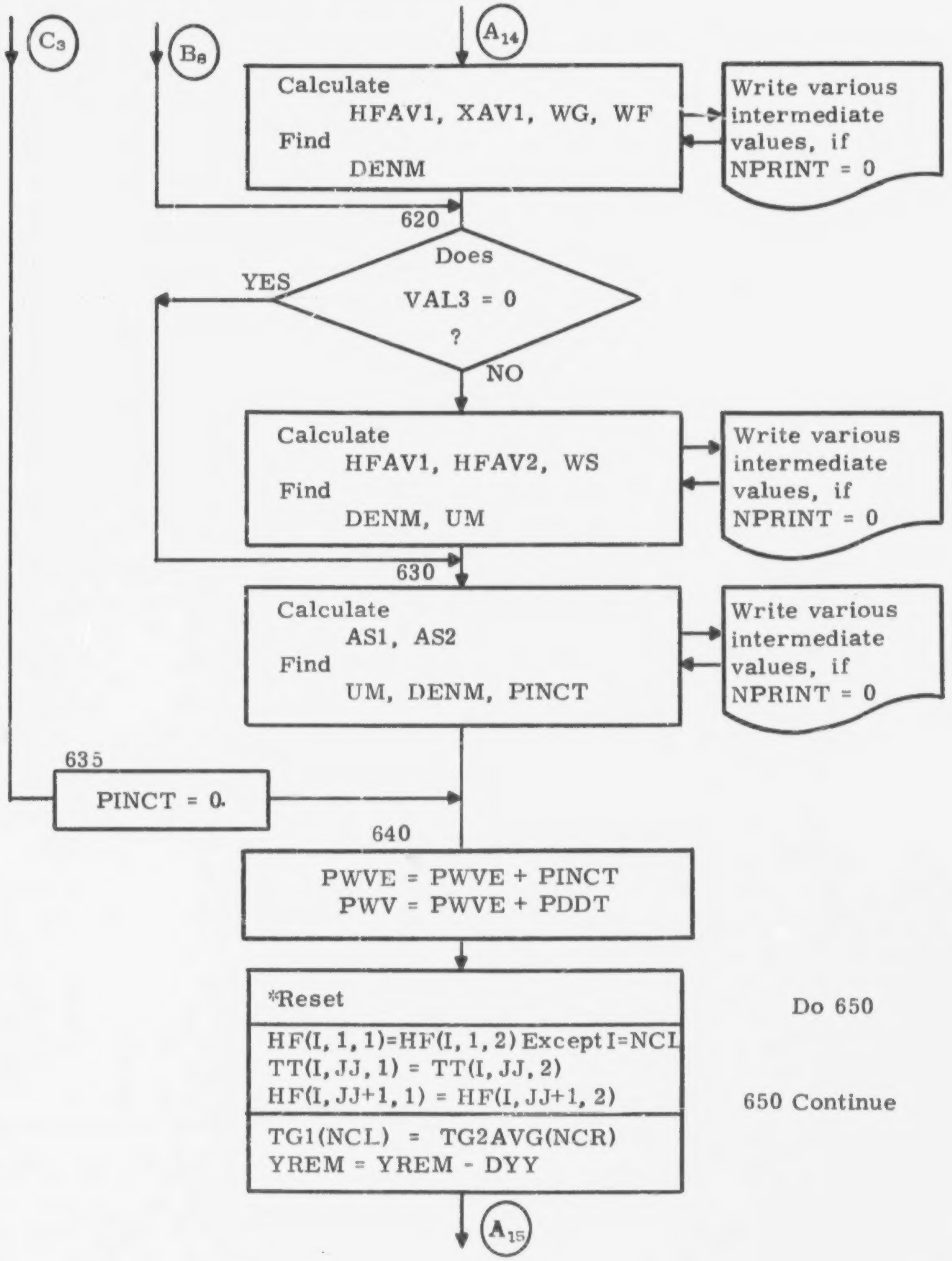
FLOW DIAGRAM -- VAPORG (Cont'd)


B7
A12
Write (on file 6) HTFY, CTFY, EFY, HGTY
5021
Does JI = NXN ?
NO
YES
Does I = NCR ?
YES
NO
Set
MWVZ(I+1, 1) = MWVZ(I, NXN+1)
HF(I+1, 1, 2) = HF(I, NXN+1, 2)
M
420
Does JI = NXN ?
NO
JI = JI + 1
YES
420 Continue
Find TG2AVG(I)
Value of (I-NCL-1) ?
1
2
3
421
TG1(NCL+1) = TGVI
423
TG1(NCR) = TG2AVG(NCL+1)
A13

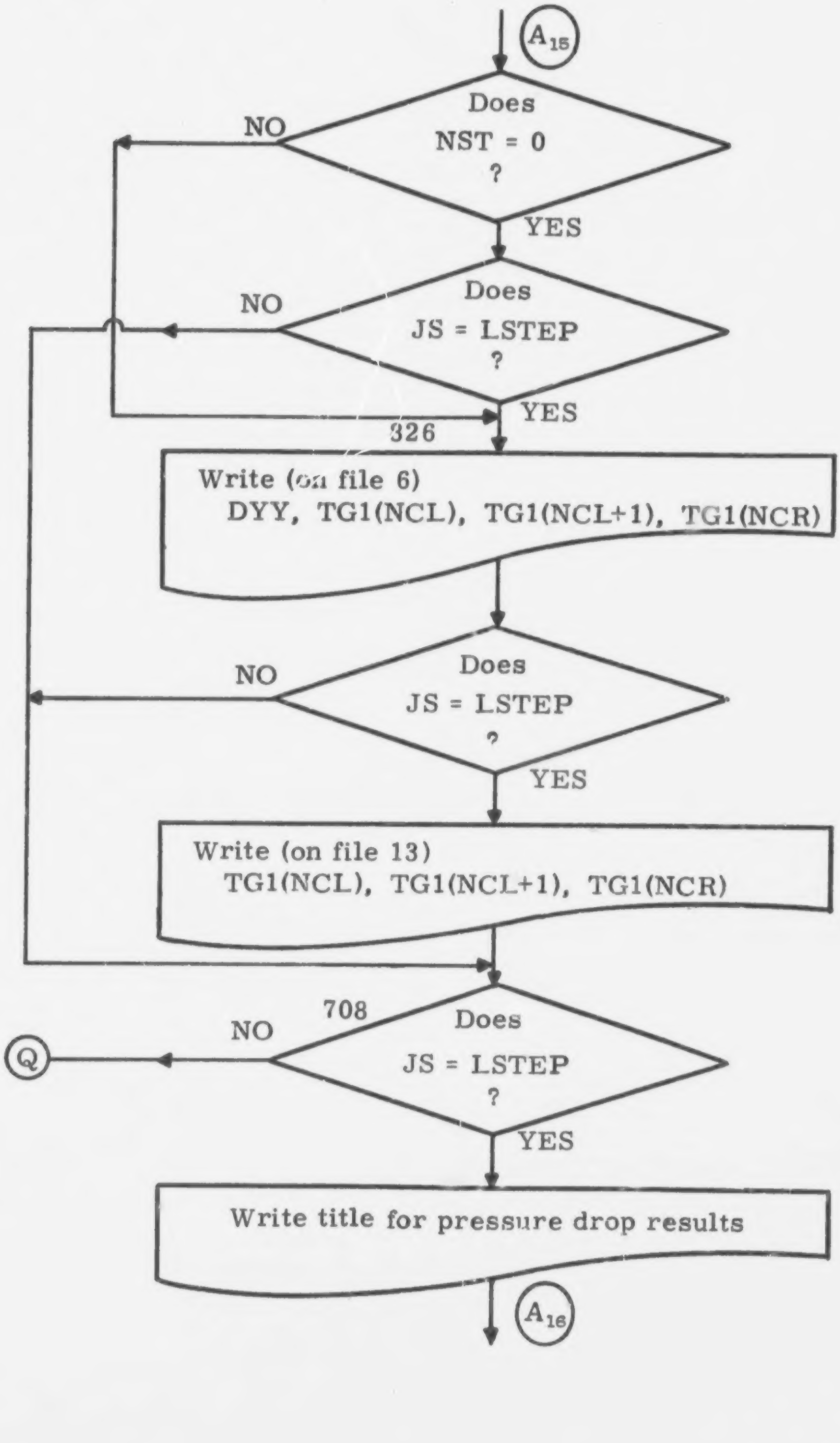
FLOW DIAGRAM -- VAPORG (Cont'd)


A13
600
Does I = NCR ?
NO
V
YES
600 Continue
TIME = TIME + DXY
Does NSS = 0 ?
YES
NO
*Pressure calculation
Initialize
VAL1, VAL2, VAL3, UM, DENM
Compute VAL1, VAL2, VAL3
Do 610
610 Continue
Does (VAL2 + VAL3) = 0 ?
YES
NO
Compute HFG, GFG
Define PLOW
Does VAL2 = 0 ?
YES
NO
C3
B8
A14

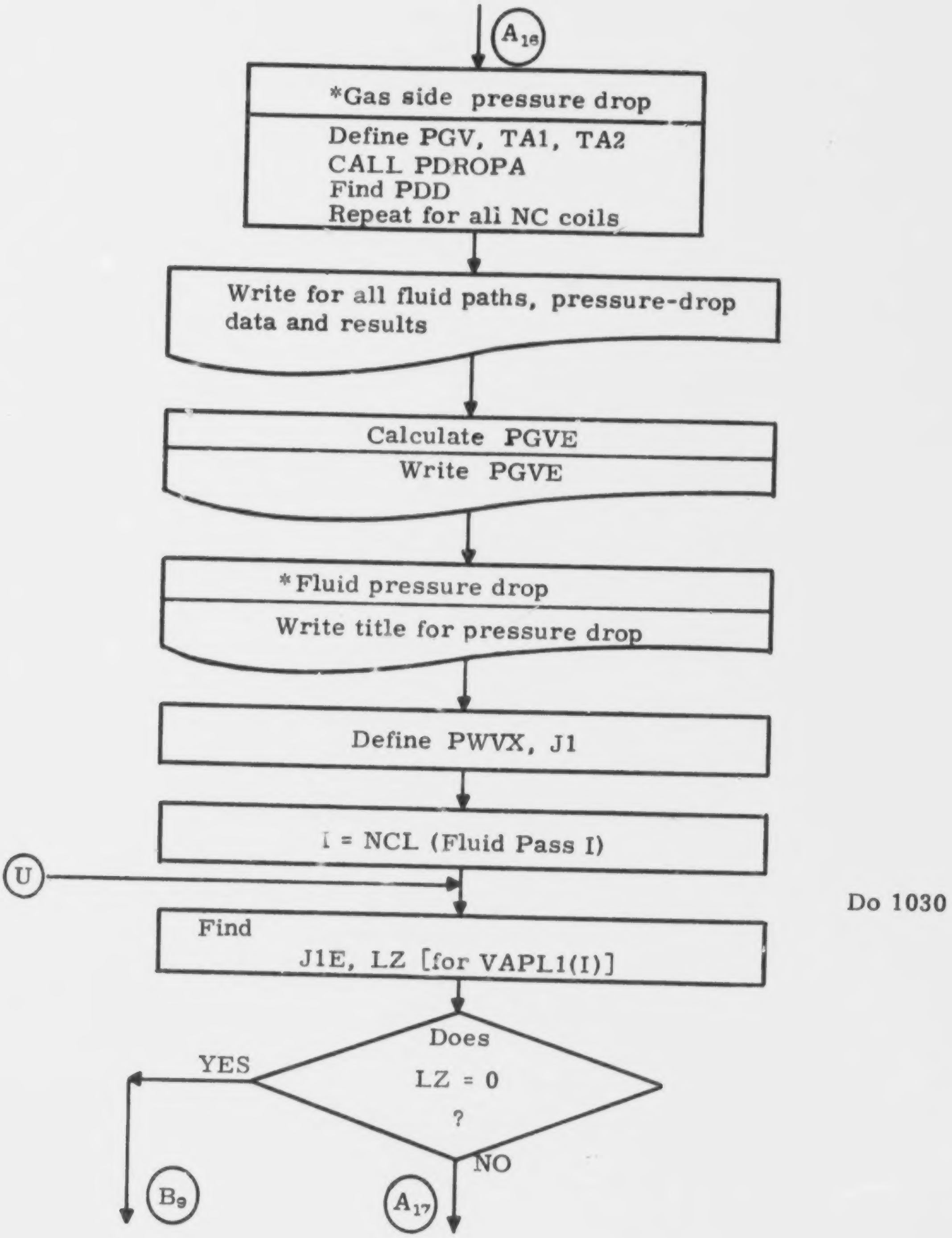
FLOW DIAGRAM -- VAPORG (Cont'd)


C3
B8
A14
Calculate
HFAV1, XAV1, WG, WF
Find
DENM
Write various intermediate values, if NPRINT = 0
620
Does VAL3 = 0 ?
YES
NO
Calculate
HFAV1, HFAV2, WS
Find
DENM, UM
Write various intermediate values, if NPRINT = 0
630
Calculate
AS1, AS2
Find
UM, DENM, PINCT
Write various intermediate values, if NPRINT = 0
635
PINCT = 0.
640
PWVE = PWVE + PINCT
PWV = PWVE + PDDT
*Reset
HF(I, 1, 1)=HF(I, 1, 2) Except I=NCL
TT(I, JJ, 1) = TT(I, JJ, 2)
HF(I, JJ+1, 1) = HF(I, JJ+1, 2)
TG1(NCL) = TG2AVG(NCR)
YREM = YREM - DYY
Do 650
650 Continue
A15

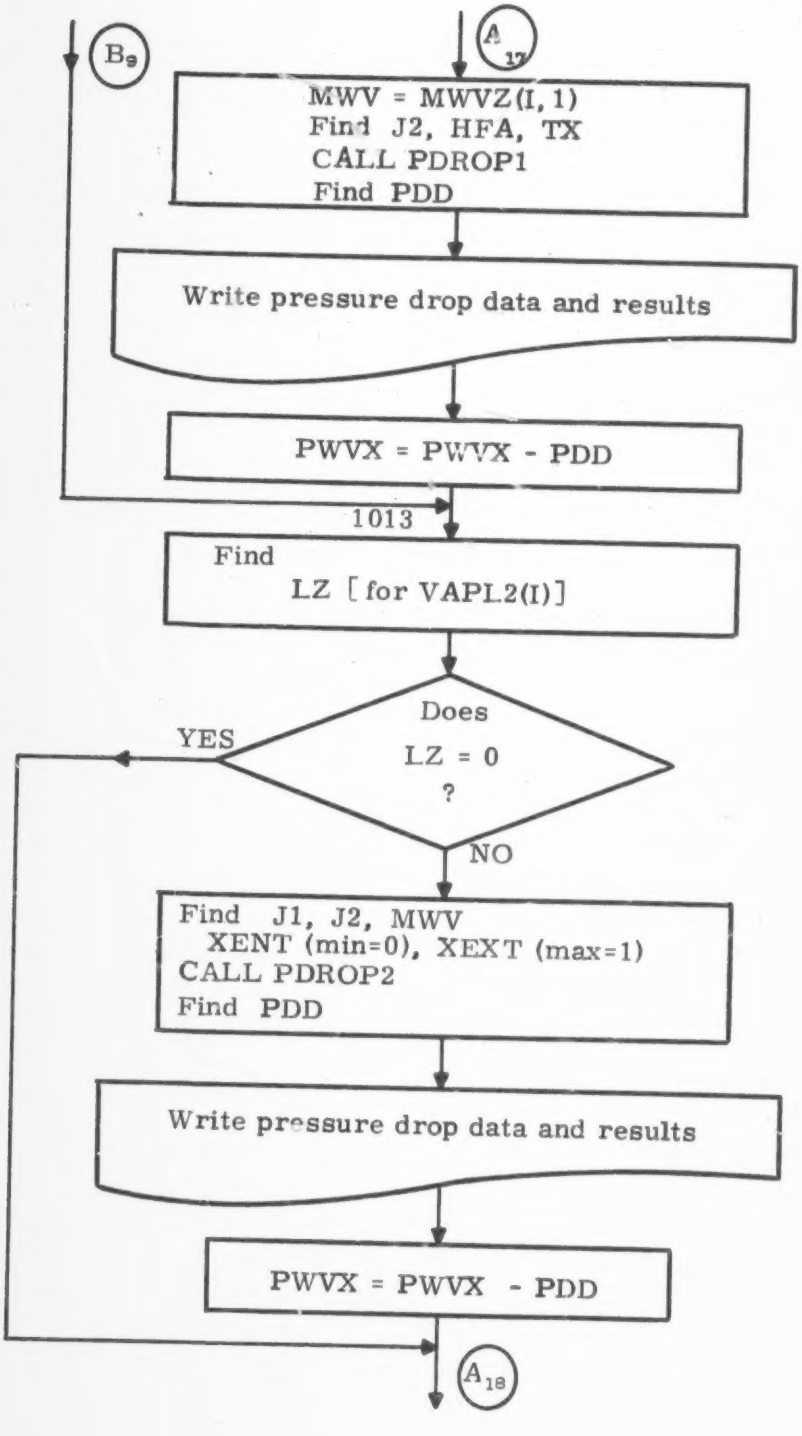
FLOW DIAGRAM -- VAPORG (Cont'd)


A15
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
326
Write (on file 6) DYY, TG1(NCL), TG1(NCL+1), TG1(NCR)
Does JS = LSTEP ?
NO
YES
Write (on file 13) TG1(NCL), TG1(NCL+1), TG1(NCR)
708
Does JS = LSTEP ?
NO
Q
YES
Write title for pressure drop results
A16

FLOW DIAGRAM -- VAPORG (Cont'd)

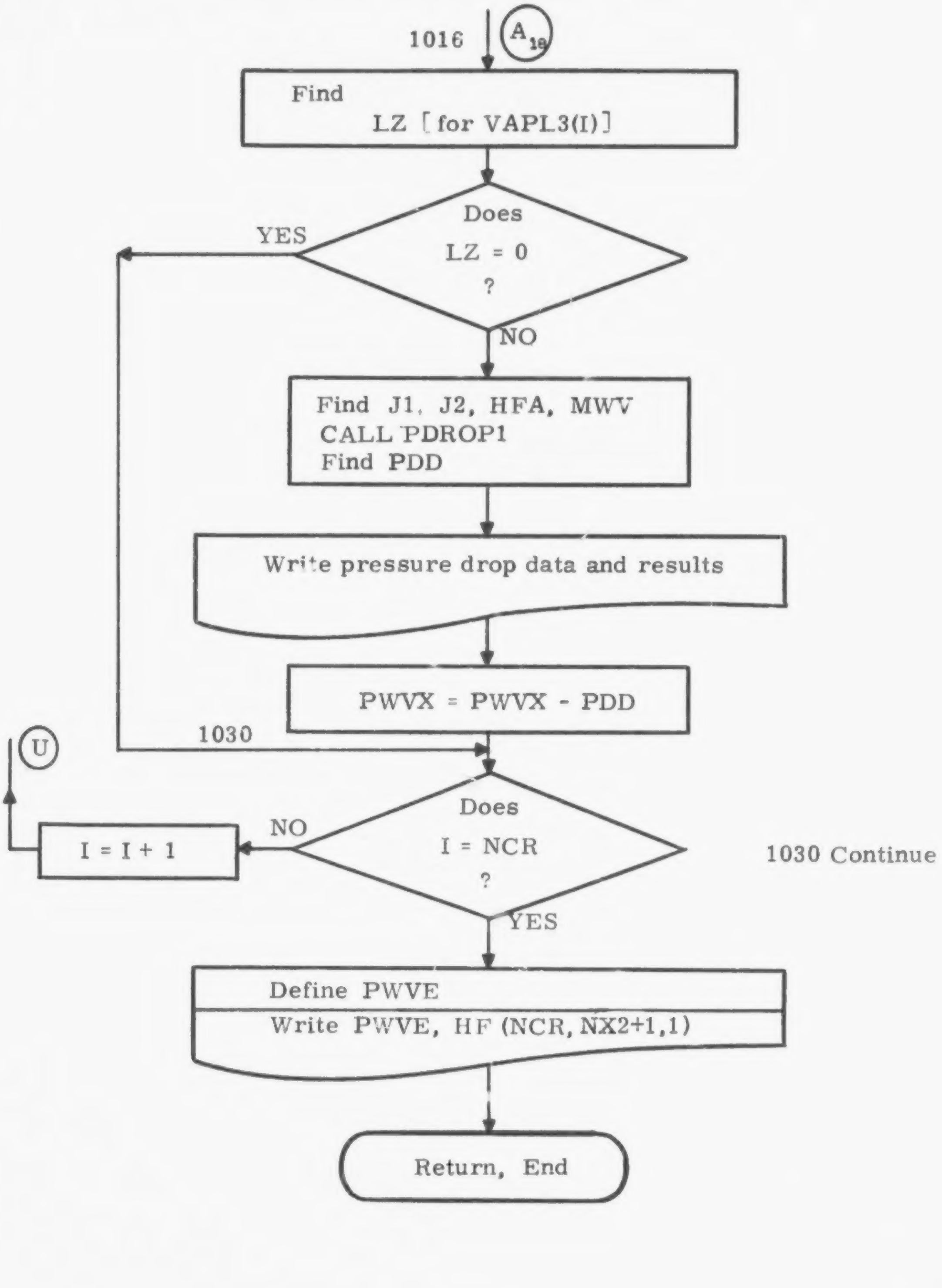

A_{16}
*Gas side pressure drop
Define PGV, TA1, TA2
CALL PDROPA
Find PDD
Repeat for all NC coils
Write for all fluid paths, pressure-drop data and results
Calculate PGVE
Write PGVE
*Fluid pressure drop
Write title for pressure drop
Define PWVX, J1
I = NCL (Fluid Pass I)
U
Do 1030
Find
J1E, LZ [for VAPL1(I)]
Does
LZ = 0
?
YES
NO
B_9
A_{17}

FLOW DIAGRAM -- VAPORG (Cont'd)



B9
A17
MWV = MWVZ(I, 1)
Find J2, HFA, TX
CALL PDROP1
Find PDD
Write pressure drop data and results
PWVX = PWVX - PDD
1013
Find
LZ [for VAPL2(I)]
Does
LZ = 0
?
YES
NO
Find J1, J2, MWV
XENT (min=0), XEXT (max=1)
CALL PDROP2
Find PDD
Write pressure drop data and results
PWVX = PWVX - PDD
A18

FLOW DIAGRAM -- VAPORG (Cont'd)


1016
A_{18}
Find
LZ [for VAPL3(I)]
Does
LZ = 0
?
YES
NO
Find J1, J2, HFA, MWV
CALL PDROP1
Find PDD
Write pressure drop data and results
PWVX = PWVX - PDD
1030
U
Does
I = NCR
?
NO
I = I + 1
1030 Continue
YES
Define PWVE
Write PWVE, HF (NCR, NX2+1,1)
Return, End

PROGRAM LISTING -- VAPORG

```
      SUBROUTINE VAPORG(MGI,MWF,PGVI,PGVE,PWVI,PWVE,TGVI,JS,NST)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,HTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),HT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,FGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGI,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NNO,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      DIMENSION MWVZ(10,11)
      REAL TZ,MFN1,MGI,MGVA(10),MGVZ(10),MWE,MWV,MWVE,MWVZ
      NTCOMP=1
*     SET NCYCLE=0 INITIALLY IN THE MAIN PROGRAM
      NC=NCY(NTCOMP)
      NCL=NCLY(NTCOMP)
      NCR=NCRY(NTCOMP)
      MWVZ(NCL,1)=MWZ(NCL,1)
      IF(NST.NE.1) MWF=MWVZ(NCL,1)
      MWVE=MWF
      PWDT=PWVI-PWVE
      DO 3 I=NCL,NCR
      IF(NCYCLE.NE.0) GO TO 811
      CALL GEOMCO(I)
 811  CONTINUE
      MGVA(I)=MGI/(12.*L(I))
      MGVZ(I)=MGI/TUBROW(I)
   3  CONTINUE
      PWV=PWVI
      IF(NTRANS.NE.0) GO TO 861
*     INITIALIZE
      DO 18 I=NCL,NCR
      NX2Z(I)=1
*     ASSUME AVERAGE VALUES,STATE RELATIONSHIPS NOT IMPORTANT
      HW=0.5*HFIN1(I)+0.5*HFIN2(I)
      TG=0.5*(TGIN1(I)+TGIN2(I))
*     A MORE ACCURATE TIZ CAN BE OBTAINED BY USING HEAT-TRANS. COEFFS.
      TIZ=TG
      A1=12.*L(I)
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
      NX2=NX2Z(I)
      CALL STEPSI(PWV,TW,HW,TG,TTZ,MWVZ(NCL,1),MGVA(I),XF,I,A1,NX2)
      IF(NX2.LE.NLUMP) GO TO 15
  10  FORMAT(36H NO. OF LUMP REQUIRED EXCEEDS NLUMP )
      WRITE(6,10)
      WRITE(6,2)NX2
   2  FORMAT(6H NX2  ,I10)
      STOP
  15  NX2Z(I)=NX2
*     INITIAL DISTRIBUTION
      IF(I.NE.NCL) HF(I,1,1)=HFIN1(I)
      TG1(I)=TGIN1(I)
      TG2(I,1,1)=TGIN2(I)
      XN2Z=FLOAT(NX2)
      DXN=12.*L(I)/XN2Z
      A2=(HFIN2(I)-HFIN1(I))/XN2Z
      MWVZ(I,1)=MWVZ(NCL,1)
      DO 18 J=1,NX2
      MWVZ(I,J+1)=MWVZ(NCL,1)
      HF(I,J+1,1)=HF(I,J,1)+A2
*     NOTE DO NOT USE TG2,TT AT NX2+1
      TG2(I,J,1)=TGIN2(I)
      TT(I,J,1)=TW+MWVZ(I,J)*A2/(HTF*DXN)
      IF(NPH.EQ.2) TT(I,J,1)=TW
  18  CONTINUE
      GO TO 220
 861  DO 862 I=NCL,NCR
      NX2=NX2Z(I)+1
      DO 862 J=1,NX2
 862  MWVZ(I,J)=MWZ(I,J)
*     ENTRY POINT AFTER FIRST CYCLE
 220  YREM=YEXT
*     AT THIS POINT THE EXTERNAL CONDITIONS ARE ENTERED FOR
*     THE NEXT EXTERNAL TIME STEP.  DURING INITIALIZATION
*     THEY SHOULD BE MADE EQUAL TO THE INITIALIZING VALUES
*     PWV FROM PRESSURE COMPUTATION
*     THE FOLLOWING IS A LOOP BACK FROM STATEMENT 1000-1
 225  CONTINUE
      HF(NCL,1,2)=HF(NCL,1,1)
      CALL SATP(PWV,TSAT,GVL,GVV,HL,HV,1)
      IF(NSS.EQ.1) GO TO 717
      JS=JS+1
      IF(JS.EQ.LSTEP) NPRINT=0
      IF(NST.NE.0) GO TO 721
      IF(JS.NE.LSTEP) GO TO 867
 721  WRITE(6,5030)TIME,JS
 724  WRITE(6,5029)
      WRITE(6,725)HF(NCL,1,1)
 725  FORMAT(29H FLUID ENTHALPY (ENTRANCE)  =,E15.5)
      WRITE(6,726)MWVZ(NCL,1)
 726  FORMAT(29H FLUID FLOW RATE (ENTRANCE) =,E15.5)
      WRITE(6,5003)PWV,TSAT
5003  FORMAT(29H FLUID PRESSURE, SAT TEMP   =,2E15.5)
      WRITE(6,816)MGI
 816  FORMAT(29H GAS FLOW RATE (ENTRANCE)   =,F15.5)
      WRITE(6,818)PGVI,TGVI
 818  FORMAT(29H GAS PRES, TEMP (ENTRANCE)  =,2E15.5)
 867  CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 717
      WRITE(13,701)TIME
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
 701  FORMAT(E15.5)
 717  CONTINUE
      DO 396 I=NCL,NCR
      NXO=NX2Z(I)
      NX2MAX(I)=1
      VAPL1(I)=0.
      VAPL2(I)=0.
      VAPL3(I)=0.
      J2E(I)=0
      J3E(I)=0
      DXO=12.*L(I)/FLOAT(NXO)
      MGVA(I)=MGI/(12.*L(I))
      MGVZ(I)=MGI/TUBROW(I)
      DO 230 JI=1,NXO
      HW=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      TA=(TG1(I)+TG2(I,JI,1))/2.
      TTZ=TT(I,JI,1)
      A1=L(I)*12.
      MWV=MWVZ(I,JI)
      NX2=NX2Z(I)
      CALL STEPSI(PWV,TW,HW,TA,TTZ,MWV,MGVA(I),XF,I,A1,NX2)
*     THE FOLLOWING ARE AVAILABLE FROM STEPSI AND ARE BULK
      RWY(I,JI)=RW
      HGTY(I,JI)=HGT
      HTFY(I,JI)=HTF
      EFY(I,JI)=EF
      CTFY(I,JI)=CTF
      NPHY(I,JI)=NPH
      NX2MAX(I)=MAX0(NX2MAX(I),NX2)
 230  CONTINUE
      NXN=NX2MAX(I)
      NX2Z(I)=NXN
      DXN=12.*L(I)/FLOAT(NXN)
      DX2=DXN
      IF(NSS.EQ.1) GO TO 727
      IF(I.EQ.NCL) DXN1=DX2
      IF(I.EQ.(NCL+1)) DXN2=DX2
      IF(NST.NE.0) GO TO 817
      IF(JS.NE.LSTEP) GO TO 728
 817  IF(I.LT.NCR) GO TO 728
      WRITE(6,729)DXN1,DXN2.DX2
 729  FORMAT(29H LUMP SIZE (COILS 1,2,3)    =,3E15.5)
      WRITE(6,5029)
 728  CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 727
      WRITE(13,730)NXN
 730  FORMAT(I10)
 727  CONTINUE
      IF(NXN.EQ.NXO) GO TO 237
      MA=NXO+1
      DO 806 JI=1,MA
 806  MWZ(I,JI)=MWVZ(I,JI)
      CALL DISTR(I)
      MA=NXN+1
      DO 807 JI=1,MA
 807  MWVZ(I,JI)=MWZ(I,JI)
      DO 236 JI=1,NXN
      HW=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      IF(HW-HL) 231,232,232
 231  NPH=1
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
      GO TO 235
 232  IF(HW-HV) 233,233,234
 233  NPH=2
      GO TO 235
 234  NPH=3
 235  NPHY(I,JI)=NPH
 236  CONTINUE
 237  DO 238  JI=1,NXN
      IF(NSS.EQ.1) GO TO 238
      NPH=NPHY(I,JI)
*     LOCATE INTERPHASES
      IF(NPH-2)229,226,227
 226  VAPL2(I)=VAPL2(I)+(DX2*ACI(I))
      J2E(I)=J2E(I)+1
      GO TO 229
 227  VAPL3(I)=VAPL3(I)+(DX2*ACI(I))
      J3E(I)=J3E(I)+1
 229  VAPL1(I)=12.*ACI(I)*L(I)-VAPL2(I)-VAPL3(I)
      IF(VAPL1(I).LT.DX2*ACI(I)/2.) VAPL1(I)=0.
 238  CONTINUE
      DYYM=YREM
      DO 265 JI=1,NXN
      X2=2.*(EFY(I,JI)/HTFY(I,JI))
      DYX1=CTT(I)/(HGTY(I,JI)+HTFY(I,JI))
      DYX2=(2.*CTFY(I,JI)/HTFY(I,JI))/((X2/DXN)+1.)
      DYX3=ABS(RHY(I,JI)*ACI(I)*DXN/(MWVZ(I,JI)*1728.))
      IF(NPHY(I,JI).EQ.1) DYY=FRAC*AMIN1(DYX1,DYX2)
      IF(NPHY(I,JI).EQ.2) DYY=FRAC*AMIN1(DYX1,DYX3)
      IF(NPHY(I,JI).EQ.3) DYY=FRAC*DYX1
      DYYM=AMIN1(DYYM,DYY)
 265  CONTINUE
      DXN=DX2
      DYYY(I)=DYYM
 396  CONTINUE
      DYY=YREM
      DO 412 I=NCL,NCR
 412  DYY=AMIN1(DYY,DYYY(I))
      IF(NSS.EQ.0) GO TO 718
      CALL ITERAT(PGVI,MGI,TSAT,MWVZ(NCL,1),HL,HV,PWVI,JS,NC,
     7NCL,1)
      JI=NX2Z(NCR)
      HEINT=HF(NCR,JI+1,1)
      IF(NSS.EQ.1) GO TO 717
      IF(NST.NE.1) GO TO 718
      WRITE(6,5030)TIME,JS
 718  CONTINUE
      INX1=1
      INX2=1
      QTOT=0.
      DO 600 I=NCL,NCR
      NXN=NX2Z(I)
      DXN=12.*L(I)/FLOAT(NXN)
      TG2T=0.
      IF(NST.NE.0) GO TO 822
      IF(JS.NE.LSTEP) GO TO 821
 822  IF(I.NE.NCL) GO TO 713
      WRITE(6,732)
 732  FORMAT(3X,5H LUMP,10X,3H H2,14X,3H TF,14X,3H TT,13X,4H TG2,
     714X,3H M2,10X,4H NPH)
 713  CONTINUE
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
      WRITE(6,20)I
   20 FORMAT(38X,5H*****,16H FLUID PASS NO. ,I5,5H*****)
  821 CONTINUE
      DO 420 JI=1,NXN
      NPH=NPHY(I,JI)
      TG=(TG1(I)+TG2(I,JI,1))/2.
      CGG=FCG(TG,RFA)
      X1=2.*MGI*CGG/(HGTY(I,JI)*L(I)*12.)
      BB=1./X1
      TGN=TG1(I)
      NBB=1
      IF(BB.GT.0.5) NBB=2.5*BB
      BB=BB/FLOAT(NBB)
      FG2G1=(1.-BB)/(1.+BB)
      FG2T=1.-FG2G1
      ADT=FG2T*TT(I,JI,1)
      DO 280 LK=1,NBB
  280 TGN=FG2G1*TGN+ADT
      TG2(I,JI,2)=TGN
      TG2(I,JI,1)=TG2(I,JI,2)
      TG2T=TG2T+TG2(I,JI,2)
      GO TO (397,398,399),NPH
  397 TREF=TSAT
      HFAVG=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      HREF=HL
      CPP=FCWL(TREF)
      TX=TREF
  803 TFX=TREF+(HFAVG-HREF)/CPP
      TX1=(TREF+TFX)/2.
      IF(ABS((TX-TX1)/TX)-.01) 805,805,804
  804 TX=TX1
      CPP=FCWL(TX)
      GO TO 803
  805 FTG=(DYY/2.)*(HGTY(I,JI)/CTT(I))
      FTT=1.-(DYY/CTT(I))*(HTFY(I,JI)+HGTY(I,JI))
      FTF=(DYY/2.)*HTFY(I,JI)/(CTT(I)*CPP)
      FCON=DYY*(HTFY(I,JI)/CTT(I))*(TREF-(HREF/CPP))
      TT(I,JI,2)=FTT*TT(I,JI,1)+FTF*(HF(I,JI,1)+HF(I,JI+1,1))+
     4FTG*(TG1(I)+TG2(I,JI,1))+FCON
      MWVZ(I,JI+1)=MWVZ(I,JI)
      FF2T=DYY*(HTFY(I,JI)/CTFY(I,JI))*CPP
      FF2F1=(DYY/DXN)*(EFY(I,JI)/CTFY(I,JI))*(1.-(HTFY(I,JI)/
     4EFY(I,JI))*(DXN/2.))
      FF2F2=1.-(DYY/CTFY(I,JI))*((HTFY(I,JI)/2.)+(EFY(I,JI)/DXN))
      HF(I,JI+1,2)=FF2F2*HF(I,JI+1,1)+FF2F1*HF(I,JI,1)+
     5FF2T*(TT(I,JI,1)-TREF+(HREF/CPP))
      HFN=HF(I,JI+1,1)
      GO TO 410
  398 IF(INX1.NE.1) GO TO 2000
      HEN1=HF(I,JI,1)
      HENN1=HF(I,JI,2)
      MEN1=MWVZ(I,JI)
      INX1=2
 2000 CONTINUE
      DRODH=((1./GVL)-(1./GVV))/(HL-HV)
      FTG=(DYY/2.)*HGTY(I,JI)/CTT(I)
      FTT=1.-(DYY/CTT(I))*(HTFY(I,JI)+HGTY(I,JI))
      FTF=DYY*HTFY(I,JI)/CTT(I)
      TT(I,JI,2)=FTT*TT(I,JI,1)+FTF*TSAT+FTG*(TG1(I)+TG2(I,JI,1))
      HAVG1=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      XE1=(HAVG1-HL)/(HV-HL)
      IF(XE1.LT.0.) XE1=0.
      IF(XE1.GT.1.) XE1=1.
      RO=(1./GVL)+XE1*((1./GVV)-(1./GVL))
      VBAR=1728./(RO*ACI(I))
      FF2F1=(DYY/DXN)*VBAR*ABS(MWVZ(I,JI))
      FF2F2=1.-FF2F1
      FF2T=DYY*VBAR*HTFY(I,JI)
      HF(I,JI+1,2)=FF2F2*HF(I,JI+1,1)+FF2F1*HF(I,JI,1)+FF2T*
     6(TT(I,JI,1)-TSAT)
      TFX=TSAT
      HFN=HF(I,JI+1,1)
      DELTH=HF(I,JI,1)-HF(I,JI+1,1)
      TDIFF=TT(I,JI,1)-TSAT
      IF((XE1.LT.0.8).AND.(TDIFF.GE.30.)) TDIFF=30.
      TERM1=TDIFF*HTFY(I,JI)*DXN
      PREF=-DRODH/RO
      WVZ=MWVZ(I,JI)
      TERM2=PREF*DELTH
      TERM3=PREF*TERM1
      WVZ=(1.+TERM2)*WVZ+TERM3
      MWVZ(I,JI+1)=WVZ
      HEX1=HF(I,JI+1,1)
      HEXN1=HF(I,JI+1,2)
      GO TO 410
  399 IF(INX2.NE.1) GO TO 827
      HFA=HF(I,JI,1)
      HFB=HF(I,JI+1,1)
      GO TO 828
  827 HFA=HF(I,JI,2)
      HFB=HF(I,JI+1,2)
  828 HFAVG=(HFA+HFB)/2.
      CALL SUPPT(PWV,TFX,HFAVG,DD,GV,3)
      GVZ(I,JI,1)=GV
      HREF=HFAVG+5.
      CALL SUPPT(PWV,TREF,HREF,DD,DS,3)
      CPP=(HFAVG-HREF)/(TFX-TREF)
      X1=ABS(2.*MWVZ(I,JI)*CPP/HTFY(I,JI))
      BB=DXN/X1
      FF2F1=(1.-BB)/(1.+BB)
      FF2T=2.*BB/(1.+BB)
      HF(I,JI+1,2)=FF2F1*HFA+FF2T*(CPP*(TT(I,JI,1)-TREF)
     6+HREF)
      HEX2=HF(I,JI+1,1)
      FTG=(DYY/2.)*(HGTY(I,JI)/CTT(I))
      FTT=1.-(DYY/CTT(I))*(HTFY(I,JI)+HGTY(I,JI))
      FTF=(DYY/2.)*HTFY(I,JI)/(CTT(I)*CPP)
      FCON=DYY*(HTFY(I,JI)/CTT(I))*(TREF-(HREF/CPP))
      TT(I,JI,2)=FTT*TT(I,JI,1)+FTF*(HFA+HF(I,JI+1,2))+
     4FTG*(TG1(I)+TG2(I,JI,1))+FCON
      HEXN2=HF(I,JI+1,2)
      HFAVG=(HF(I,JI,2)+HF(I,JI+1,2))/2.
      CALL SUPPT(PWV,TWV,HFAVG,DD,GV,3)
      GVZ(I,JI,2)=GV
      HFN=HF(I,JI+1,1)
      MWVZ(I,JI+1)=MWVZ(I,JI)+(DXN/DYY)*ACI(I)*(GVZ(I,JI,2)-
     7GVZ(I,JI,1))/(GVZ(I,JI,1)*GVZ(I,JI,2)*1728.)
  410 CONTINUE
      QTOT=QTOT+HTFY(I,JI)*DXN*(TT(I,JI,1)-TFX)
 5029 FORMAT(2H  )
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
5030  FORMAT(40H                                    ***** TIME = ,E15.5,
     721H          (TIMESTEP NO.,I5,2H ))
      IF(NST.NE.0) GO TO 736
      IF(JS.NE.LSTEP) GO TO 868
 736  WRITE(6,5032)JI,HFN,TFX,TT(I,JI,1),TG2(I,JI,1),
     7MWVZ(I,JI+1),NPHY(I,JI)
5032  FORMAT(I6,4X,5E17.5,I6)
 868  CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 706
      WRITE(13,705)HFN,TT(I,JI,1),TG2(I,JI,1),MWVZ(I,JI+1)
 705  FORMAT(4E15.5)
 706  CONTINUE
      IF(NPRINT.NE.0) GO TO 5021
      WRITE(6,5033)HTFY(I,JI),CTFY(I,JI),EFY(I,JI),HGTY(I,JI)
5033  FORMAT(17H HTF,CTF,EF,HGT  ,4E15.5)
5021  CONTINUE
      IF(JI.NE.NXN) GO TO 420
      IF(I.EQ.NCR) GO TO 420
      MWVZ(I+1,1)=MWVZ(I,NXN+1)
      HF(I+1,1,2)=HF(I,NXN+1,2)
 420  CONTINUE
      TG2AVG(I)=TG2T/FLOAT(NXN)
      IF(I-NCL-1) 421,423,600
 421  TG1(NCL+1)=TGVI
      GO TO 600
 423  TG1(NCR)=TG2AVG(NCL+1)
 600  CONTINUE
      TIME=TIME+DYY
*     PRESSURE CALCULATION
      VAL1=0.
      VAL2=0.
      VAL3=0.
      UM=0.
      DENM=0.
      DO 610 J=NCL,NCR
      VAL1=VAL1+VAPL1(J)
      VAL2=VAL2+VAPL2(J)
 610  VAL3=VAL3+VAPL3(J)
      IF((VAL2+VAL3).EQ.0.) GO TO 635
      VAL=VAL1+VAL2+VAL3
      HFG=HV-HL
      GFG=GVV-GVL
      AX=GFG/HFG
      DELH=2.
      DELP=2.
      PLOW=PWV-DELP
      IF(VAL2.EQ.0.) GO TO 620
      HFAV1=(HEN1+HEX1)/2.
      XAV1=(HFAV1-HL)/(HV-HL)
      IF(XAV1.LT.0.0) XAV1=0.
      IF(XAV1.GT.1.) XAV1=1.
      WG=XAV1*VAL2/(1728.*GVV)
      WF=(1.-XAV1)*VAL2/(1728.*GVL)
      CALL SATP(PLOW,DD,GVL1,GVV1,HL1,HV1,1)
      AR1=WG*(HV-HV1)/DELP
      AR2=WF*(HL-HL1)/DELP
      AR3=WF*(GVL-GVL1)/DELP
      AR4=WG*(GVV-GVV1)/DELP
      DENM=DENM+AX*(AR1+AR2)-(AR3+AR4)
      IF(NPRINT.NE.0) GO TO 620
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
      WRITE(6,823)HEN1,HEX1,HFAV1
      WRITE(6,823)HL,HV,XAV1,VAL2,GVV,GVL
      WRITE(6,823)HG,WF,PLOW,GVL1,GVV1
      WRITE(6,823)HL1,HV1,DELP,AR1,AR2
      WRITE(6,823)AR3,AR4,DENM,AX
  823 FORMAT(7H VAP1  ,6E15.5)
  620 IF(VAL3.EQ.0.) GO TO 630
      HFAV1=(HEX1+HEX2)/2.
      HFAV2=(HEXN1+HEXN2)/2.
      CALL SUPPT(PWV,TAV1,HFAV1,DD,GAV1,3)
      CALL SUPPT(PLOW,DD,HFAV1,DD,GAV2,3)
      CALL SUPPT(PWV,DD,HFAV1+DELH,DD,GAV3,3)
      WS=VAL3/(1728.*GAV1)
      AX1=(GAV3-GAV1)/DELH
      AX2=WS*(GAV1-GAV2)/DELP
      UM=UM+WS*(AX1-AX)*(HFAV2-HFAV1)/DYY
      DENM=DENM-AX2
      IF(NPRINT.NE.0) GO TO 630
      WRITE(6,824)UM,DENM
  824 FORMAT(7H VAP2  ,2E15.5)
  630 NX2=NX2Z(NCR)
      AS1=AX*(QTOT-MWVZ(NCL,1)*(HL-HF(NCL,1,1))-MWE*
     7(HF(NCR,NX2+1,1)-HL))
      AS2=(MWVZ(NCL,1)-MWE)*GVL
      UM=UM+AS1+AS2
      DENM=DENM-AX*VAL/(12.*778.)
      PINCT=UM*DYY/DENM
      IF(NPRINT.NE.0) GO TO 640
      WRITE(6,825)HFAV1,HEX1,HEX2
      WRITE(6,825)HFAV2,HEXN1,HEXN2
      WRITE(6,825)TAV1,GAV1,GAV2,GAV3
      WRITE(6,825)VAL3,WS,AX1,DELP,AX2
      WRITE(6,825)UM,AX,DYY,DENM
      WRITE(6,825)AS1,QTOT
      WRITE(6,825)MWVZ(NCL,1),HL,HF(NCL,1,1),MWE
      WRITE(6,825)HF(NCR,NX2+1,1),AS2,GVL
  825 FORMAT(7H VAP3  ,5E15.5)
      WRITE(6,5062)PINCT
 5062 FORMAT(8H PINCT  ,E15.5)
      GO TO 640
  635 PINCT=0.
  640 PWVE=PWVE+PINCT
      PWV=PWVE+PDOT
      WRITE(6,5029)
*     RESET
      DO 650 I=NCL,NCR
      NXN=NX2Z(I)
      IF(I.EQ.NCL) GO TO 645
      HF(I,1,1)=HF(I,1,2)
  645 CONTINUE
      MWZ(1,NXN+1)=MWVZ(I,NXN+1)
      DO 650 JJ=1,NXN
      TT(I,JJ,1)=TT(I,JJ,2)
      HF(I,JJ+1,1)=HF(I,JJ+1,2)
      MWZ(I,JJ)=MWVZ(I,JJ)
  650 CONTINUE
      TG1(NCL)=TG2AVG(NCR)
      YREM=YREM-DYY
      IF(NST.NE.0) GO TO 826
      IF(JS.NE.LSTEP) GO TO 869
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
  826 WRITE(6,48)DYY,TG1(NCL),TG1(NCL+1),TG1(NCR)
   48 FORMAT(10H DYY,TG1  ,4E15.5)
  869 CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 708
      WRITE(13,707)TG1(NCL),TG1(NCL+1),TG1(NCR)
  707 FORMAT(3E15.5)
  708 CONTINUE
      IF(JS.NE.LSTEP) GO TO 225
*     GAS-SIDE PRESSURE DROP
      WRITE(6,5029)
      WRITE(6,5029)
      WRITE(6,42)
   42 FORMAT(46X,28H ** PRESSURE DROP RESULTS **)
      WRITE(6,851)
  851 FORMAT(12H ** GAS SIDE)
      WRITE(6,852)
  852 FORMAT(3X,5H COIL,7X,10H MASS FLOW,9X,8H INLET P,10X,
     78H INLET T,10X,7H EXIT T,10X,9H PR. DROP)
 1000 CONTINUE
      PGV(NCL+1)=PGVI
      TA1=TG1(NCL+1)
      TA2=TG2AVG(NCL+1)
      J=NCL+1
      CALL PDROPA(PGV(J),TA1,TA2,MGVZ(J),NSO(J),DHO(J),DO(J),ACO(J),
     1 L(J),X2L(J),FNO(J),FHO(J),FTO(J),RM(J),PDD)
      WRITE(6,853)J,MGVZ(J),PGV(J),TG1(J),TG2AVG(J),PDD
  853 FORMAT(I6,4X,5E17.5)
      PGV(NCR)=PGV(NCL+1)-PDD
      TA1=TG1(NCR)
      TA2=TG2AVG(NCR)
      J=NCR
      CALL PDROPA(PGV(J),TA1,TA2,MGVZ(J),NSO(J),DHO(J),DO(J),ACO(J),
     2 L(J),X2L(J),FNO(J),FHO(J),FTO(J),RM(J),PDD)
      WRITE(6,853)J,MGVZ(J),PGV(J),TG1(J),TG2AVG(J),PDD
      PGV(NCL)=PGV(NCR)-PDD
      TA1=TG1(NCL)
      TA2=TG2AVG(NCL)
      J=NCL
      CALL PDROPA(PGV(J),TA1,TA2,MGVZ(J),NSO(J),DHO(J),DO(J),ACO(J),
     3 L(J),X2L(J),FNO(J),FHO(J),FTO(J),RM(J),PDD)
      WRITE(6,853)J,MGVZ(J),PGV(J),TG1(J),TG2AVG(J),PDD
      WRITE(6,5029)
      PGVE=PGV(NCL)-PDD
      WRITE(6,854)PGVE,TG2AVG(NCL)
  854 FORMAT(25H EXIT PRESSURE, TEMP    =,2E15.5)
      WRITE(6,5029)
      WRITE(6,5029)
*     FLUID PRESSURE DROP
      WRITE(6,856)
  856 FORMAT(14H ** FLUID SIDE)
      WRITE(6,857)
  857 FORMAT(3X,5H COIL,9X,5H FLOW,14X,4H NPH,12X,7H LENGTH,
     79X,11H INLET PRES,8X,9H PR. DROP)
      PWVX=PWV
      J1=1
      DO 1030 I=NCL,NCR
      J1E=NX2Z(I)-(J2E(I)+J3E(I))
      LZ=VAPL1(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1013
      MWV=MWVZ(I,1)
```

PROGRAM LISTING -- VAPORG (Cont'd)

```
1012  CALL SATP(PWVX,TWV,DD,DD,HL,HV,1)
      J2=J1E+J1
      HFA=(HF(I,1,1)+HF(I,J2,1))/2.
      TX=TWV
5070  CW=FCWL(TX)
      TW=TWV+(HFA-HL)/CW
      TX1=.5*(TWV+TW)
      IF(ABS(TX-TX1)/TX-.01)5071,5071,5072
5072  TX=TX1
      GO TO 5070
5071  CALL PDROP1(PWVX,TW,MWV,DHI(I),ACI(I),LZ,1,PDD,DD,DD,DD)
      NPH=1
      WRITE(6,858)I,MWV,NPH,LZ,PWVX,PDD
 858  FORMAT(I6,4X,E17.5,I9,8X,3E17.5)
      PWVX=PWVX-PDD
1013  LZ=VAPL2(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1016
      J1=J1E+1
      J2=J2E(I)+J1
      MWV=(MWVZ(I,J1)+MWVZ(I,J2))/2.
      CALL SATP(PWVX,TWV,DD,DD,HL,HV,1)
      XENT=(HF(I,J1,1)-HL)/(HV-HL)
      XEXT=(HF(I,J2,1)-HL)/(HV-HL)
      IF(XENT.LT.0.) XENT=0.
      IF(XEXT.GT.1.) XEXT=1.
      CALL PDROP2(PWVX,TWV,XENT,XEXT,MWV,DHI(I),ACI(I),LZ,PDD)
      NPH=2
      WRITE(6,858)I,MWV,NPH,LZ,PWVX,PDD
      PWVX=PWVX-PDD
1016  LZ=VAPL3(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1030
      J1=J2E(I)+J1E+1
      J2=J3E(I)+J1
      HFA=(HF(I,J1,1)+HF(I,J2,1))/2.
      MWV=(MWVZ(I,J1)+MWVZ(I,J2))/2.
      CALL SUPPT(PWVX,TWV,HFA,DD,DD,3)
      CALL PDROP1(PWVX,TWV,MWV,DHI(I),ACI(I),LZ,3,PDD,DD,DD,DD)
      NPH=3
      WRITE(6,858)I,MWV,NPH,LZ,PWVX,PDD
      WRITE(6,5029)
      PWVX=PWVX-PDD
1030  CONTINUE
      PWVE=PWVX
      NX2=NX2Z(NCR)
      WRITE(6,859)PWVE,HF(NCR,NX2+1,1)
 859  FORMAT(25H EXIT PRESSURE, ENTH    =,2E15.5)
      RETURN
      END
```

SUBROUTINE DISTR

DISTR calculates new nodal distribution (NXN nodes) from previous distribution (NXO nodes), by linear interpolation, for VAPORG.

NOMENCLATURE -- DISTR

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of DISTR are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
I	Fluid pass number	--

PROGRAM LISTING -- DISTR

```
      SUBROUTINE DISTR(I)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2F(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL    L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      DIMENSION SCF1(30),SCF2(30),SCF3(30),SCF4(30),SCF5(30)
      DIMENSION SCF6(30),SCF7(30),SCF8(30)
      IF(NXO.EQ.NXN) RETURN
      IF(NXO.GT.NLUMP.OR.NXN.GT.NLUMP) GO TO 20
      GO TO 60
   20 WRITE(6,50)
   50 FORMAT(27H NO. OF LUMPS EXCEEDS NLUMP)
      STOP
   60 XNN=FLOAT(NXN)
*     NOTE SINCE SCF1,SCF2,SCF3,SCF4,SCF5,NSCF ARE ONLY SCRATCH ARRAY
*     WE NEED NOT TRANSFER TFO(1),HFO(1),PFO(1)
      SCF1(NXN+1)=MWZ(I,NXO+1)
      SCF2(NXN+1)=HF(I,NXO+1,1)
      DO 100 N=2,NXN
      J=1+NXO*(N-1)/NXN
      A1=FLOAT((N-1)*NXO-(J-1)*NXN)/XNN
      SCF1(N)=MWZ(I,J)+A1*(MWZ(I,J+1)-MWZ(I,J))
      SCF2(N)=HF(I,J,1)+A1*(HF(I,J+1,1)-HF(I,J,1))
  100 CONTINUE
      NTEM=NXN+1
      DO 200 N=2,NTEM
      MWZ(I,N)=SCF1(N)
      HF(I,N,1)=SCF2(N)
  200 CONTINUE
      DO 300 N=1,NXO
      J=.5+.5*FLOAT((2*N-1)*NXO)/XNN
*     NOTE THAT J CAN NEVER EXCEED NXO OR BE LESS THAN 0
      IF(J.EQ.0) GO TO 290
```

PROGRAM LISTING -- DISTR (Cont'd)

```
      IF(J.EQ.NXO) GO TO 295
      A1=.5*FLOAT((2*N-1)*NXO-(2*J-1)*NXN)/XNN
      SCF1(N)=TT(I,J,1)+A1*(TT(I,J+1,1)-TT(I,J,1))
      SCF2(N)=TG2(I,J,1)+A1*(TG2(I,J+1,1)-TG2(I,J,1))
      SCF3(N)=HGTY(I,J)+A1*(HGTY(I,J+1)-HGTY(I,J))
      SCF4(N)=EGY(I,J)+A1*(EGY(I,J+1)-EGY(I,J))
      SCF5(N)=HTFY(I,J)+A1*(HTFY(I,J+1)-HTFY(I,J))
      SCF6(N)=EFY(I,J)+A1*(EFY(I,J+1)-EFY(I,J))
      SCF7(N)=CTFY(I,J)+A1*(CTFY(I,J+1)-CTFY(I,J))
      SCF8(N)=RWY(I,J)+A1*(RWY(I,J+1)-RWY(I,J))
      GO TO 300
 290  A1=.5*FLOAT(NXN-(2*N-1)*NXO)/XNN
      SCF1(N)=TT(I,1,1)-A1*(TT(I,2,1)-TT(I,1,1))
      SCF2(N)=TG2(I,1,1)-A1*(TG2(I,2,1)-TG2(I,1,1))
      SCF3(N)=HGTY(I,1)-A1*(HGTY(I,2)-HGTY(I,1))
      SCF4(N)=EGY(I,1)-A1*(EGY(I,2)-EGY(I,1))
      SCF5(N)=HTFY(I,1)-A1*(HTFY(I,2)-HTFY(I,1))
      SCF6(N)=EFY(I,1)-A1*(EFY(I,2)-EFY(I,1))
      SCF7(N)=CTFY(I,1)-A1*(CTFY(I,2)-CTFY(I,1))
      SCF8(N)=RWY(I,1)-A1*(RWY(I,2)-RWY(I,1))
      IF(SCF1(N).LE.0.) SCF1(N)=TT(I,1,1)
      IF(SCF2(N).LE.0.) SCF2(N)=TG2(I,1,1)
      IF(SCF3(N).LE.0.) SCF3(N)=HGTY(I,1)
      IF(SCF4(N).LE.0.) SCF4(N)=EGY(I,1)
      IF(SCF5(N).LE.0.) SCF5(N)=HTFY(I,1)
      IF(SCF6(N).LE.0.) SCF6(N)=EFY(I,1)
      IF(SCF7(N).LE.0.) SCF7(N)=CTFY(I,1)
      IF(SCF8(N).LE.0.) SCF8(N)=RWY(I,1)
      GO TO 300
 295  A1=.5*FLOAT(NXO*(2*N-1)-NXN*(2*NXO-1))/XNN
      SCF1(N)=TT(I,NXO,1)+A1*(TT(I,NXO,1)-TT(I,NXO-1,1))
      SCF2(N)=TG2(I,NXO,1)+A1*(TG2(I,NXO,1)-TG2(I,NXO-1,1))
      SCF3(N)=HGTY(I,NXO)+A1*(HGTY(I,NXO)-HGTY(I,NXO-1))
      SCF4(N)=EGY(I,NXO)+A1*(EGY(I,NXO)-EGY(I,NXO-1))
      SCF5(N)=HTFY(I,NXO)+A1*(HTFY(I,NXO)-HTFY(I,NXO-1))
      SCF6(N)=EFY(I,NXO)+A1*(EFY(I,NXO)-EFY(I,NXO-1))
      SCF7(N)=CTFY(I,NXO)+A1*(CTFY(I,NXO)-CTFY(I,NXO-1))
      SCF8(N)=RWY(I,NXO)+A1*(RWY(I,NXO)-RWY(I,NXO-1))
      IF(SCF1(N).LE.0.) SCF1(N)=TT(I,NXO,1)
      IF(SCF2(N).LE.0.) SCF2(N)=TG2(I,NXO,1)
      IF(SCF3(N).LE.0.) SCF3(N)=HGTY(I,NXO)
      IF(SCF4(N).LE.0.) SCF4(N)=EGY(I,NXO)
      IF(SCF5(N).LE.0.) SCF5(N)=HTFY(I,NXO)
      IF(SCF6(N).LE.0.) SCF6(N)=EFY(I,NXO)
      IF(SCF7(N).LE.0.) SCF7(N)=CTFY(I,NXO)
      IF(SCF8(N).LE.0.) SCF8(N)=RWY(I,NXO)
 300  CONTINUE
      DO 400 N=1,NXN
      TT(I,N,1)=SCF1(N)
      TG2(I,N,1)=SCF2(N)
      HGTY(I,N)=SCF3(N)
      EGY(I,N)=SCF4(N)
      HTFY(I,N)=SCF5(N)
      EFY(I,N)=SCF6(N)
      CTFY(I,N)=SCF7(N)
      RWY(I,N)=SCF8(N)
 400  CONTINUE
      RETURN
      END
```

SUBROUTINE GEOMCO

GEOMCO calculates all geometric constants for VAPORG.

NOMENCLATURE -- GEOMCO

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of GEOMCO are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
NC	Fluid pass number	--

PROGRAM LISTING -- GEOMCO

```
      SUBROUTINE GEOMCO(NC)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL    L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
*     HYDRAULIC DIAMETERS
*     USE FUNCTIONS
      VOLB=(3.1416/4.)*(DO(NC)**2-DI(NC)**2)
      MI=NSO(NC)
      GO TO(10,20,30),MI
   10 ACO(NC)=X2L(NC)-DO(NC)
      DHO(NC)=(4./3.1416)*ACO(NC)
      GO TO 40
   20 A1=FNO(NC)*FHO(NC)
      A2=A1*FTO(NC)
      A3=DO(NC)+2.*FHO(NC)
      ACO(NC)=X2L(NC)-DO(NC)-2.*A2
      ENO=3.1416*A1*(A3+2.*FTO(NC))
      DHO(NC)=4.*ACO(NC)*A3/(ENO+3.1416*DO(NC))
      VOLO=A2*(FHO(NC)+DO(NC))*3.1416
      GO TO 40
   30 A1=1.-RM(NC)
      A2=X2L(NC)-DO(NC)
      BH(NC)=A2
      ACO(NC)=A2*RM(NC)
      DHO(NC)=4.*RM(NC)*DS(NC)/(6.*A1)
      VOLO=A1*A2*BT(NC)
   40 MI=NSI(NC)
      GO TO(50,55),MI
   50 ACI(NC)=(3.1416/4.)*(DI(NC)**2)
      DHI(NC)=DI(NC)
      GO TO 60
   55 VOLI=FNI(NC)*FTI(NC)*FHI(NC)
```

PROGRAM LISTING -- GEOMCO (Cont'd)

```
      ACI(NC)=(3.1416/4.)*DI(NC)*DI(NC)-VOLI
      DHI(NC)=4.*ACI(NC)/(3.1416*DI(NC)+2.*FNI(NC)*FHI(NC))
   60 CONTINUE
*     TUBE METAL PROPERTIES ARE ASSUMED CONSTANT IN THIS PROGRAM
*     ARRANGEMENT
      TX=0.
      MI=NM(NC)
      GO TO (140,145),MI
*     NOTE THAT AI PRESENTLY FORMULATED THE FUNCTIONS FCMS(TX),
*     FRMS(TX),FCMC(TX),FRMC(TX). THEY DO NOT DEPEND ON TEMPERATURE
*     WHICH IS NOT DEFINED AT THIS POINT. (SUITABLE TEMPERATURES
*     COULD BE DEFINED FOR THIS PURPOSE)
  140 CTB=FCMS(TX)
      RTB=FRMS(TX)
      GO TO 150
  145 CTB=FCMC(TX)
      RTB=FRMC(TX)
  150 MI=NSO(NC)
      IF(MI.EQ.1) GO TO 165
      MI=NMO(NC)
      GO TO(155,160),MI
  155 CTO=FCMS(TX)
      RTO=FRMS(TX)
      GO TO 165
  160 CTO=FCMC(TX)
      RTO=FRMC(TX)
  165 MI=NSI(NC)
      IF(MI.EQ.1) GO TO 180
      MI=NMI(NC)
      GO TO(170,175),MI
  170 CTI=FCMS(TX)
      RTI=FRMS(TX)
      GO TO 180
  175 CTI=FCMC(TX)
      RTI=FRMC(TX)
  180 CTT(NC)=VOLB*CTB*RTB
      IF(NSO(NC).NE.1) CTT(NC)=CTT(NC)+VOLO*CTO*RTO
      IF(NSI(NC).NE.1) CTT(NC)=CTT(NC)+VOLI*CTI*RTI
      CTT(NC)=CTT(NC)/1728.
      RETURN
      END
```

SUBROUTINE STEPSI

STEPSI calculates the stability limit on lump size for each lump of VAPORG. STEPSI employs the following subroutines:

HT1PB
HT2PB
HTGR
HTGTB
HTGTF
HTGTM
HTPF
PHASE

NOMENCLATURE -- STEPSI

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of STEPSI are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
HW	Enthalpy of working fluid	Btu/lb
MGV	Mass flow rate of gas	lb/sec
MWV	Mass flow rate of working fluid	lb/sec
NC	Fluid pass number	--
NX2	Number of lumps for a given coil	--
PW	Pressure of working fluid	$lb/in.^2$
TG	Bulk gas temperature	°F
TI	Wall temperature at mid-node of a lump	°F
TW	Bulk fluid temperature	°F
X	Quality of bulk mass within a lump	--
X2G	Geometric limit on lump size	in.

PROGRAM LISTING -- STEPSI

```
      SUBROUTINE STEPSI(PW,TW,HW,TG,TI,MWV,MGV,X,NC,X2G,NX2)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXM,NXO
      COMMON PGV(10),PFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),INB
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MWV,MGV
*     PW,HW,TG,TI,MWV,MGV,NC,X2G ARE INPUT
*     NX2,X,TW ARE RETURNED.
      CALL PHASE(PW,TW,HW,X,GVL,GVV,HL,HV)
*     GAS PROPERTIES
      CG=FCG(TG,RFA)
      RG=1./FDG(TG,RFA)
*     OBTAIN HEAT TRANS COEFFS; HTGT HTTF
*     OBTAINING HTGT
      G=MGV/ACO(NC)
      MI=NSO(NC)
      GO TO (10,20,30),MI
 10   CALL HTGTB(HTGT,NC,G,TG)
      GO TO 40
 20   CALL HTGTF(HTGT,NC,G,TG)
      GO TO 40
 30   CALL HTGTM(HTGT,NC,G,TG
 40   CONTINUE
      CALL HTGR(HTC,TG,TI)
      HTGT=HTGT+HTC
*     OBTAINING HTTF
      GF=ABS(MWV/ACI(NC))
      MI=NSI(NC)
      GO TO (50,80,90),MI
 50   GO TO (60,70,60),NPH
 60   CALL HT1PH(HTTF,NC,GF,PW,TW)
      GO TO 100
```

PROGRAM LISTING -- STEPSI (Cont'd)

```
  70   CALL HT2PB(HTTF,NC,GF,TW,TI,X,PW,GVL,GVV,HL,HV)
       GO TO 100
  80   CALL HTPF(HTTF,NC,GF,PW,TW,TI,X,GVL,GVV,HL,HV)
       GO TO 100
  90   WRITE (6,500)
 500   FORMAT(52H HEAT TRANSFER NOT FORMULATED FOR BALL MATRIX INSIDE)
       STOP
 100   CONTINUE
*      COMPUTE THT PARAMETERS
       EG=ABS(MGV*12.*L(NC))*CG/FLOAT(NX2)
       EF=ABS(MWV*CW)
       HGT=HTGT*3.14159*DO(NC)
       HTF=HTTF*3.14159*DI(NC)
       CTF=RW*ACI(NC)*CW/1728.
*      STEP SIZE CALCULATION
       X2=2.*EF/HTF
       DX2=AMIN1(X2*FRAC,X2G)
       NX2=INTSTE(DX2,X2G)
       IF(NPH.EQ.2) NX2=10
       IF(NX2.GT.1) DX2=X2G/FLOAT(NX2)
       RETURN
       END
```

SUBROUTINE ITERAT

ITERAT gives an iterative solution for steady-state distribution of fluid enthalpy, gas temperature, and tube temperature. It employs the subroutine SUPPT.

The data file referenced in ITERAT by the two-digit code 15 is a storage file for the values calculated before exiting ITERAT the final time. Since the data in the file vary according to the particular run just completed, a listing is not included here.

NOMENCLATURE -- ITERAT

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of ITERAT are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
HL	Enthalpy of working fluid liquid	Btu/lb
HV	Enthalpy of working fluid vapor	Btu/lb
JS	Variable to denote cumulative number of timesteps	--
MGV	Mass flow rate of the gas	lb/sec
NC	Fluid pass number	--
NCL	First fluid pass number for the component	--
NCOD	Logic variable to denote component: 1 - vapor generator 2 - condenser 3 - regenerator	--
PGG	Pressure of gas	$lb/in.^2$
PWV	Pressure of working fluid vapor	$lb/in.^2$
TSAT	Saturated temperature of working fluid	^{o}F
W	Mass flow rate of working fluid	lb/sec

PROGRAM LISTING -- ITERAT

```
      SUBROUTINE ITERAT(PGG,MGV,TSAT,W,HL,HV,PWV,JS,NC,NCL,
     7NCOD)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,IO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL    L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MGV
      JS=JS+1
      NCR=NCL+NC-1
      MA=NX27(NCR)+1
      HEXIT=HF(NCR,MA,1)
      DO 100 I=NCL,NCR
      TG2T=0.
      NXN=NX2Z(I)
      DXN=12.*L(I)/FLOAT(NXN)
      MI=NX2Z(I)
      DO 90 JI=1,MI
      NPH=NPHY(I,JI)
      TG=(TG1(I)+TG2(I,JI,1))/2.
      GO TO (10,12,15),NCOD
 10   CGG=FCG(TG,RFA)
      GO TO 18
 12   CGG=FCA(TG)
      GO TO 18
 15   CGG=FCWV(PGG,TG)
 18   CONTINUE
      BB=HGTY(I,JI)*L(I)*12./(2.*MGV*CGG)
      TGL=TG1(I)
      NBB=1
      IF(BB.GT.0.5) NBB=2.5*BB
      BB=BB/FLOAT(NBB)
      FG2G1=(1.-BB)/(1.+BB)
      FG2I=1.-FG2G1
```

PROGRAM LISTING -- ITERAT (Cont'd)

```
      HTF=HTFY(I,JI)
      HGT=HGTY(I,JI)
      H2=HF(I,JI+1,1)
      H1=HF(I,JI,1)
   20 TGN=TG1(I)
      ADT=FG2T*TT(I,JI,1)
      DO 280 LK=1,NBB
  280 TGN=FG2G1*TGN+ADT
      TG2(I,JI,1)=TGN
      GO TO (30,40,30),NPH
   30 IF(NPH.EQ.3) GO TO 35
      CP=EFY(I,JI)/W
      HR=HL
      TR=TSAT
      GO TO 38
   35 HAVG=(H1+H2)/2.
      CALL SUPPT(PWV,TFY,HAVG,DD,DD,3)
      HR=HAVG+5.
      CALL SUPPT(PWV,TR,HR,DD,DD,3)
      CP=(HAVG-HR)/(TFY-TR)
   38 CONTINUE
      F1=HTF/(2.*CP*(HGT+HTF))
      F2=HGT/(2.*(HGT+HTF))
      TFX=TR-(HR/CP)
      F3=(HTF/(HGT+HTF))*TFX
      BB=HTF*DXN/(2.*W*CP)
      F4=(1.-BB)/(1.+BB)
      F5=2.*CP*BB/(1.+BB)
      TT(I,JI,1)=F1*(H1+H2)+F2*(TG1(I)+TG2(I,JI,1))+F3
      H2=F4*H1+F5*(TT(I,JI,1)-TFX)
      GO TO 50
   40 F1=HTF/(HGT+HTF)
      F2=HGT/(2.*(HGT+HTF))
      F5=DXN*HTF/W
      TT(I,JI,1)=F1*TSAT+F2*(TG1(I)+TG2(I,JI,1))
      H2=H1+F5*(TT(I,JI,1)-TSAT)
   50 CONTINUE
      IF(ABS(TGL-TG2(I,JI,1))/TGL-1.E-5)60,60,55
   55 TGL=TG2(I,JI,1)
      GO TO 20
   60 TG2T=TG2T+TG2(I,JI,1)
      HF(I,JI+1,1)=H2
   90 CONTINUE
      TG2AVG(I)=TG2T/FLOAT(NXN)
      IF(I.NE.NCR) HF(I+1,1,1)=H2
  100 CONTINUE
      GO TO (102,104,106),NCOD
  102 TG1(NCL)=TG2AVG(NCR)
      TG1(NCR)=TG2AVG(NCL+1)
      GO TO 108
  104 TG1(NCL+1)=TG2AVG(NCL)
      TG1(NCR)=TG2AVG(NCL+1)
      GO TO 108
  106 TG1(NCL+2)=TG2AVG(NCR)
      TG1(NCL+1)=TG2AVG(NCL+2)
      TG1(NCL)=TG2AVG(NCL+1)
  108 IF(JS.LT.13) GO TO 109
      WRITE(6,107)
  107 FORMAT(33H DIDN'T CONVERGE IN 13 ITERATIONS)
      STOP
```

PROGRAM LISTING -- ITERAT (Cont'd)

```
109   IF((ABS((HEXIT-H2)/H2))-5.E-5) 130,130,110
110   CONTINUE
      RETURN
130   MI=JS-1
      WRITE(15,131)MI
131   FORMAT(I15)
      DO 133 J=NCL,NCR
      WRITE(15,132)NX2Z(J)
132   FORMAT(I10)
133   CONTINUE
      DO 140 J=NCL,NCR
      MI=NX2Z(J)
      DO 140 JI=1,MI
      WRITE(15,135)HF(J,JI+1,1),T1(J,JI,1),TG2(J,JI,1)
      WRITE(15,135)HTFY(J,JI),HGTY(J,JI)
135   FORMAT(3E15.5)
140   CONTINUE
      WRITE(15,142)(TG1(J),J=NCL,NCR)
142   FORMAT(4E15.5)
      DO 141 I=NCL,NCR
      MI=NX2Z(I)
141   CONTINUE
      NSS=0
      JS=0
      RETURN
      END
```

SUBROUTINE PDROP1

PDROP1 calculates the single-phase fluid pressure drop.

NOMENCLATURE -- PDROP1

FORTRAN Variables in COMMON:

FORTRAN variables in the COMMON of PDROP1 are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
AG	Flow cross-section area	in.^{2}
DH	Flow hydraulic diameter	in.
DP	Fluid pressure drop for straight tube length	lb/in.^{2}
DPB	Fluid pressure drop for bends in tube	lb/in.^{2}
L	Fluid travel length	in.
NBEND	Number of bends in tube	--
NF	Logic variable: 1 - working fluid -- liquid 2&3 - working fluid -- vapor 4 - combustor	--
P	Bulk fluid inlet pressure	lb/in.^{2}
RFA	Fuel to air ratio	--
T	Average fluid temperature	°F
W	Mass flow rate	lb/sec

PROGRAM LISTING -- PDROP1

```
      SUBROUTINE PDROP1(P,T,W,DH,AC,L,NF,DP,RFA,NBEND,DPB)
*     PR DROP -- SINGLE PHASE
*     CODF NF   1 - WORKING FLUID - LIQ; 3 - W.F.-VAPOR;
*          4 - COMBUSTOR
      REAL L,NBEND
*     AT T, ORTAIN V, RO
      GO TO (1,2,2,4),NF
    1 V=FVWL(T)
      RO=1./FDWL(T)
      GO TO 5
    2 V=FVWV(T)
      RO=1./FDWV(P,T,NF)
      GO TO 5
    4 V=FVG(T)
      RO=1./(FDG(T,RFA))
    5 CONTINUF
*     CALCULATE REY NU.
      G=W/AC
      GC=32.17
      REY=ABS((12.*3600.)*(G*DH/V))
*     CALCULATE F OR OBTAIN FROM EXP DATA
      IF(REY.GE.2.E4) F=.046/(REY**.2)
      IF((REY.LT.2.E4).AND.(REY.GE.3.E3)) F=.0791/(REY**.25)
      IF(REY.LT.3.E3) F=16./REY
*     CALCULATE DELTA P (PSI)
      DP=(24.*144./GC)*(F*L*G*G/(RO*DH))
      GO TO (6,6,6,7),NF
    7 DPB=(2.*144./GC)*(F*G*G*NBEND/RO)
    6 RETURN
      END
```

SUBROUTINE PDROP2

PDROP2 calculates the two-phase fluid pressure drop. It employs the subroutine PDROP1.

NOMENCLATURE -- PDROP2

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of PDROP2 are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
AC	Flow cross-section area	in.^{2}
DH	Flow hydraulic diameter	in.
DP	Fluid pressure drop for straight tube length	lb/in.^{2}
L	Fluid travel length	in.
PI	Bulk fluid inlet pressure	lb/in.^{2}
TI	Average fluid temperature	°F
W	Mass flow rate	lb/sec
XE	Quality of working fluid at exit	--
XI	Quality of working fluid at inlet	--

PROGRAM LISTING -- PDROP2

```
      SUBROUTINE PDROP2(PI,TI,XI,XE,W,DH,AC,L,DP)
*     PRESSURE DROP -- TWO PHASE
      REAL L
*     ACCELERATION PRESSURE DROP
      ROLI=1./FDWL(TI)
      ROVI=1./FDWV(PI,TI,1)
      G=W/AC
      GC=32.17
      DPA=(144./GC)*(G*G)*((XI-XE)/ROLI+(XE-XI)/ROVI)
*     FRICTION PRESSURE DROP
      CALL PDROP1(PI,TI,W,DH,AC,L,1,DPO,DD,DD,DD)
      VISL=FVWL(TI)
      VISV=FVWV(TI)
      XAV=(XI+XE)/2.
      XTT=((ROVI/ROLI)*((VISL/VISV)**.2)+(((1./XAV)-1.)**1.8))**.5
      IF(XTT.LT.0.1) XTT=.1
      IF(XTT.GT.100.) XTT=100.
      ZZ=ALOG(XTT)
      PHI=EXP(1.4516-8.688E-4*ZZ+5.463E-2*(ZZ**2)
     1-.4784*(ZZ**3))
      IF(PHI.LE.1.E-10) PHI=0.
      DPDP=(PHI)**2*((1.-XAV)**1.8)
      DPF=DPO*DPDP
*     TOTAL PRESSURE DROP
      DP=DPA+DPF
      RETURN
      END
```

SUBROUTINE PDROPA

PDROPA calculates the air-side pressure drop for VAPORG.

NOMENCLATURE -- PDROPA

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of PDROPA are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

The FORTRAN variables are applicable for air and gas.

FORTRAN Variable	Definition	Units
ACOL	Flow cross-section area per unit length	in.
D	Tube diameter, outside	in.
DH	Hydraulic flow diameter	in.
DP	Pressure drop	$lb/in.^2$
FH	Fin height	in.
FN	Number of fins per inch	1 per in.
FT	Fin thickness	in.
L	Tube length	in.
NS	Logic variable to denote nature of outside tube surface 1 - bare 2 - fin 3 - ball matrix	--
P1	Inlet pressure	$lb/in.^2$
RM	Porosity of ball matrix	--
T1	Inlet temperature	°F
T2	Exit temperature	°F
TSP	Tube spacing transverse to the bulk air flow direction	in.
W	Mass flow rate	lb/sec

PROGRAM LISTING -- PDROPA

```
      SUBROUTINE PDROPA(P1,T1,T2,W,NS,DH,D,ACOL,L,TSP,FN,FH,FT,RM,DP)
*     CODE NS 1=BARE;2=FIN;3=BALL
      REAL L,K1,K2
      GC=32.17
      T=(T1+T2)/2.
      AC=ACOL*L
      G=W/AC
      V=FVG(T)
      R01=.0763*(P1/14.69)*(520./(T1+460.))
      R02=R01*(T1+460.)/(T2+460.)
      REY=(12.*3600.)*(G*DH/V)
      GO TO (10,20,30),NS
10    SIG=(TSP-D)/TSP
      CF=.3906*(TSP/D)-.3321
      F=CF*(REY**(-.18))
      SA=4.*D/DH
      K1=0
      K2=0
      GOTO 40
20    SIG=(TSP-D-2.*FH*FT)/TSP
      F=.151*(REY**(-.246))
      SA=4.*(D+2.*FH)/DH
      K1=.8+SIG*(.065+SIG*(.685+.395*SIG))
      K2=1.+SIG*(-2.46+SIG*(1.573-.87*SIG))
      GOTO 40
30    SIG=RM
      SA=4.*D/DH
      F=78.63*(REY**(-1.179))+1.397*(REY**(-.1452))
      K1=0
      K2=0
  40  CONTINUE
      PREF=(144./GC)*(G*G/(2.*R01))
      AR1=K1+1.-SIG*SIG
      AR2=2.*((R01/R02)-1.)
      AR3=F*SA*(R01+R02)/(R02*2.)
      AR4=(1.-SIG*SIG-K2)*(R01/R02)
      DP=PREF*(AR1+AR2+AR3-AR4)
      RETURN
      END
```

SUBROUTINE INTSTE

INTSTE calculates the integer number of distance steps (lumps), allowing for geometric constraint.

NOMENCLATURE -- INTSTE

FORTRAN Variables in COMMON:

There is no COMMON block in INTSTE.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
DX	Lump length	in.
X	Total length	in.

PROGRAM LISTING -- INTSTE

```
      FUNCTION INTSTE(DX,X)
      INTSTE=X/DX
      XT=DX*FLOAT(INTSTE)
      IF(XT.LT.X) INTSTE=INTSTE+1
      RETURN
      END
```

SUBROUTINE PHASE

PHASE determines the fluid phase, based on gross fluid values for the lump. It employs the subroutines SATP and SUPPT.

NOMENCLATURE -- PHASE

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of PHASE are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
GVL	Specific volume of liquid	ft^3/lb
GVV	Specific volume of vapor	ft^3/lb
HL	Enthalpy of liquid	Btu/lb
HV	Enthalpy of vapor	Btu/lb
HW	Enthalpy of working fluid	Btu/lb
PW	Pressure of working fluid	$lb/in.^2$
TW	Bulk fluid temperature	°F
XW	Quality of bulk mass within a lump	--

PROGRAM LISTING -- PHASE

```
      SUBROUTINE PHASE(PW,TW,HW,XW,GVL,GVV,HL,HV)
      COMMON AP,B,CH,CHH,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BM(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),WFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
*     DECIDE FLUID PHASE.  PW AND HW ARE INPUT
*     XW,GVL,GVV,HL,HV,NPH,CW,RW,TW ARE RETURNED
      CALL SATP(PW,TSAT,GVL,GVV,HL,HV,1)
      IF(HW-HL) 200,195,195
 195  IF(HW-HV)210,220,220
 200  NPH=1
      TX=TSAT
 201  CW=FCWL(TX)
      TW=TSAT+(HW-HL)/CW
      TX1=.5*(TSAT+TW)
      IF(ABS(TX-TX1)/TX-.01) 203,203,202
 202  TX=TX1
      GO TO 201
 203  RW=1./GVL
*     THE FOLLOWING STATEMENT
*     INSERTED FOR PURPOSE OF INTERPOLATION IN DISTR
      XW=0.
      GO TO 230
 210  NPH=2
      TW=TSAT
      HFG=HV-HL
      XW=(HW-HL)/HFG
      CW=XW*FCWV(PW,TW)+(1.-XW)*FCWL(TW)
      RW=(XW/GVV)+((1.-XW)/GVL)
      GO TO 230
 220  NPH=3
      CALL SUPPT(PW,TW,HW,S,GV,3)
      CW=FCWV(PW,TW)
```

PROGRAM LISTING -- PHASE (Cont'd)

```
      RW=1./GV
*     THE FOLLOWING STATEMENT
*     INSERTED FOR PURPOSE OF INTERPOLATION IN DISTR
      XW=1.
 230  CONTINUE
      RETURN
      END
```

SUBROUTINE HTIPB

HT1PB calculates the heat transfer coefficient between a single-phase fluid and the inside of a bare tube.

NOMENCLATURE -- HT1PB

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HT1PB are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
G	Mass velocity	lb/in.^{2} sec
HTC	Heat transfer coefficient	Btu/sec in.^{2} $^\circ$F
NC	Fluid pass number	--
PRES	Fluid pressure	lb/in.^{2}
TEMP	Fluid temperature	$^\circ$F

PROGRAM LISTING -- HT1PB

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```
      SUBROUTINE HT1PB(HTC,NC,G,PRES,TEMP)
*     THIS SUBROUTINE CALCULATES THE HEAT TRANSFER COEFFICIENT
*     BETWEEN A SINGLE PHASE FLUID (SUPERHEATED NPH=3 OR SUB-
*     COOLED NPH=1) AND THE INSIDE SURFACE OF A BARE TUBE.
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STB,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2F(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSFCT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),PFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),INO
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL K
      G=ABS(G)
      GO TO (10,20,30),NPH
   10 K=FKWL(TEMP)
      V=FVWL(TEMP)
      C=FCWL(TEMP)
      GO TO 100
   20 WRITE (6,25)
   25 FORMAT (19H CALLED FOR 2 PHASE)
      STOP
   30 K=FKWV(TEMP)
      V=FVWV(TEMP)
      C=FCWV(PRES,TEMP)
*     NOTE 43200=12*3600
  100 REL=43200.*G*DHI(NC)/V
      PRL=C*V/K
      HTC=.023*REL**.8*PRL**.4*K/DHI(NC)
      HTC=HTC/43200.
      RETURN
      END
```

SUBROUTINE HT2PB

HT2PB calculates the heat transfer coefficient between a two-phase fluid (boiling) and the inside surface of a bare tube. It employs the subroutine SATP.

NOMENCLATURE -- HT2PB

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HT2PB are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
DFL	Specific volume of liquid	ft^3/lb
DFV	Specific volume of vapor	ft^3/lb
G	Mass velocity of working fluid	$lb/in.^2$ sec
HFL	Enthalpy of liquid	Btu/lb
HFV	Enthalpy of vapor	Btu/lb
HTC	Heat transfer coefficient	Btu/sec $in.^2$ °F
NC	Fluid pass number	--
PPF	Fluid pressure	$lb/in.^2$
TI	Wall temperature at mid-node of a lump	°F
TTF	Bulk fluid temperature	°F
X	Quality of bulk mass within a lump	--

PROGRAM LISTING -- HT2PB

```
      SUBROUTINE HT2PB(HTC,NC,G,TTF,TI,X,PPF,DFL,DFV,HFL,HFV)
*     THIS SUBROUTINE CALCULATES THE HEAT TRANSFER COEFFICIENT
*     BETWEEN A TWO PHASE FLUID AND THE INSIDE SURFACE OF A BARE
*     TUBE.  TF IS THE BULK FLUID TEMPERATURE AND TI IS THE INSIDE
*     TUBE WALL TEMPERATURE.
*     NOTE THAT DFL,DFV,HFL,HFV,PF ARE PROVIDED FROM THE CALLING
*     PROGRAM
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL KL,KV,KX
      G=ABS(G)
*     CHECKING TO MAKE SURE NOT SINGLE PHASE
      IF(X.EQ.(1.).OR.X.EQ.(0.))GO TO 500
*     THE FOLLOWING ARE NEEDED REGARDLESS WHETHER X<>.8
      VISL=FVWL(TTF)
      VISV=FVWV(TTF)
      KL=FKWL(TTF)
      XE=X
      IF(X.GT.(0.8)) X=.8
      RHOL=1./DFL
      RHOV=1./DFV
      CPL=FCWL(TTF)
*     NOTE THAT SURFACE TENSION UNITS MUST BE LBM/FT
      SIGMA=FYWL(TTF)
      TX=TI
      IF(ABS(TX-TTF).GT.20.) TX=TTF+20.
      CALL SATP(PI,TX,DIL,DIV,HIL,HIV,0)
      DP=144.*ABS(PI-PPF)
      DT=ABS(TI-TTF)
*     NOTE 43200=12*3600
      REL=43200.*G*DHI(NC)/VISL
      PRL=CPL*VISL/KL
```

PROGRAM LISTING -- HT2PB (Cont'd)

```
*     EVALUATING F=FUNCTION(XT),SEE MPR 6
      XT=(X/(1.-X))**.9*SQRT(RHOL/RHOV)*(VISV/VISL)**.1
      IF(XT.GT.(.1)) GO TO 10
      F=1.
      GO TO 100
  10  IF(XT.GT.(.4))GO TO 20
      F=1.996*XT**.300
      GO TO 100
  20  IF(XT.GT.(2.))GO TO 30
      F=2.730*XT**.642
      GO TO 100
  30  F=2.584*XT**.721
*     EVALUATING SC=FUNCTION(REL*F**1.25)
 100  ARG=REL*F**1.25
      IF(ARG.GT.(1.E4)) GO TO 150
      SC=.9
      GO TO 300
 150  IF(ARG.GE.(2.E4)) GO TO 210
      SC=2.282-.150*ALOG(ARG)
      GO TO 300
 210  IF(ARG.GE.(2.E5))GO TO 220
      SC=3.343-.257*ALOG(ARG)
      GO TO 300
 220  IF(ARG.GE.(4.E5))GO TO 230
      SC=2.032-.150*ALOG(ARG)
      GO TO 300
 230  SC=.1
 300  CONTINUE
      H1=.023*REL**.8*PRL**.4*KL*F/DHI(NC)
*     NOTE 4.17312E8=32.2*3600**2
      H2=.00122*4.17312E8**.25*KL**.79*CPL**.45*RHOL**.49*DP**.75
     1*(DT/((HFV-HFL)*RHOV))**.24*SC/(SQRT(SIGMA)*VISL**.29)
*     NOTE 43200=12*3600
      HTC=(H1+H2)/43200.
      HTC1=HTC
      IF(XE.GT.(0.8)) GOTO 400
      RETURN
 400  KV=FKWV(TTF)
      CPV=FCWV(PPF,TTF)
      UX=VISV
      KX=KV
      REL=43200.*G*DHI(NC)/UX
      PRL=CPV*UX/KX
      HTC=.023*REL**.8*PRL**.4*KX/DHI(NC)
      HTC=HTC/43200.
      HTC=HTC1+(XE-.8)*(HTC-HTC1)/.2
      X=XE
      RETURN
 500  WRITE (6,720)
 720  FORMAT (50H QUALITY X=1 OR 0 AS INPUT TO THIS 2 PHASE PROGRAM)
      STOP
      END
```

SUBROUTINE HTGR

HTGR calculates the radiative heat transfer coefficient between combustion gas and the tube surface of the vapor generator.

NOMENCLATURE -- HTGR

FORTRAN Variables in COMMON:

There is no COMMON block in HTGR.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
HTC	Heat transfer coefficient	Btu/ sec $in.^2$ °F
TAA	Bulk gas temperature	°F
TWA	Wall temperature at mid-node of a lump	°F

PROGRAM LISTING -- HTGR

```
      SUBROUTINE HTGR(HTC,TAA,TWA)
      IF(TAA.GT.TWA) GO TO 10
      HTC=0.
      RETURN
   10 TAA=TAA+460.
      TWA=TWA+460.
      SB=.1713E-8
      EW=.9
      EH2O=.04
      EPH2O=.08
      ECO2=.05
      EPCO2=.07
      QCO2=SB*EW*(ECO2*TAA**4-EPCO2*TWA**4)
      QH2O=SB*EW*(EH2O*TAA**4-EPH2O*TWA**4)
      HTC=(QCO2+QH2O)/(TAA-TWA)
*     NOTE 518400=144*3600
      HTC=HTC/518400.
      IF(HTC.LT.0.) HTC=0.
      TAA=TAA-460.
      TWA=TWA-460.
      RETURN
      END
```

SUBROUTINE HTGTB

HTGTB calculates the heat transfer coefficient between air (or gas) and a bare tube.

NOMENCLATURE -- HTGTB

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HTGTB are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
G	Mass velocity of gas	lb/in.^{2} sec
HTC	Heat transfer coefficient	Btu/sec in.^{2} °F
NC	Fluid pass number	--
TEMP	Bulk gas temperature	°F

PROGRAM LISTING -- HTGTB

```
          SUBROUTINE HTGTB(HTC,NC,G,TEMP)
          COMMON AP,B,CH,CHR,CO
          COMMON CO2P,CO2S,DCS,DCT,DTH
          COMMON EQUIV,F,FS,H2OP,H2OS
          COMMON HP,HR,HTFLAM,HTIN,LHV
          COMMON LHVT,LCS,LCT,MAIR,MFLUID
          COMMON MFUEL,N2P,N2R,N2S,NBENDA
          COMMON NBENDG,NO,NP,O2P,O2R
          COMMON O2S,PO,SP1,SSA,STA
          COMMON STG,TO,WS,WT,YEXT
          COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
          COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
          COMMON DI(10),DO(10),DS(10),DYYY(10),EF
          COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
          COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
          COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
          COMMON HGIN2(10),HG1,HGTY(10,11),HTF,HTFY(10,11)
          COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
          COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
          COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
          COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
          COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
          COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
          COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
          COMMON TIME,TT(10,11,2),TUPROW(10),VAPL1(10),VAPL2(10)
          COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
          COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
          COMMON NLINE,[illegible],NPSTEP,NTSTEP,P(128)
          COMMON PTAB(7[illegible]TAB(69,27),T(128),TTAB(33),VLIQ(128)
          COMMON VTAB(69,27),VVAP(128)
          REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
          REAL KG
          KG=FKG(TEMP)
          VISG=FVG(TEMP)
          CPG=FCG(TEMP,RFA)
    *     NOTE 43200=12*3600
          REG=43200.*G*DHO(NC)/VISG
          PRG=VISG*CPG/KG
          HTC=.237*REG**(-.4)*PRG**(-.667)*CPG*G
          RETURN
          END
```

SUBROUTINE HTGTF

HTGTF calculates the heat transfer coefficient between air (or gas) and a finned tube surface.

NOMENCLATURE -- HTGTF

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HTGTF are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
G	Mass velocity of gas	lb/in.^{2} sec
HTC	Heat transfer coefficient	Btu/sec in.^{2} °F
NC	Fluid pass number	--
TEMP	Bulk gas temperature	°F

PROGRAM LISTING -- HTGTF

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```
      SUBROUTINE HTGTF(HTC,NC,G,TEMP)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCI,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NRENDA
      COMMON NRENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,XT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),FF
      COMMON EFY(10,11),FG,FGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2F(10),J3F(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NST(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NNO,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL    L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL KG
      KG=FKG(TEMP)
      VISG=FVG(TEMP)
      CPG=FCG(TEMP,RFA)
*     NOTE 43200=12*3600
      REG=43200.*G*DHO(NC)/VISG
      PRG=VISG*CPG/KG
      HHTO=.1632*REG**(-.388)*PRG**(-.667)*CPG*G
*     NOTE 86400=2*12*3600
      BTO=SQRT(86400.*HHTO/(FKC(TEMP)*FTO(NC)))
      ETA=BTO*FHO(NC)
      ETA=TANH(ETA)/ETA
      A1=(FHO(NC)+FTO(NC))/DO(NC)
      A2=2.*FHO(NC)*(1.+A1)
      ATAB=1.+FNO(NC)*A2
      AFAT=FNO(NC)*(FTO(NC)+A2)/ATAB
      EFF=1.-AFAT*(1.-ETA)
      HTC=EFF*HHTO*ATAB
*     NOTE HHTO CONTAINS 43200 FACTOR
      RETURN
      END
```

SUBROUTINE HTGTM

HTGTM calculates the heat transfer coefficient between combustion gas and a ball-matrix tube surface.

NOMENCLATURE -- HTGTM

FORTRAN Variables in COMMON:

The FORTRAN Variables in the COMMON of HTGTM are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
G	Mass velocity of gas	lb/in.^{2} sec
HTC	Heat transfer coefficient	Btu/sec in.^{2} °F
NC	Fluid pass number	--
TEMP	Bulk gas temperature	°F

PROGRAM LISTING -- HTGTM

```
      SUBROUTINE HTGTM(HTC,NC,G,TEMP)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HIIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL KG
      KG=FKG(TEMP)
      VISG=FVG(TEMP)
      CPG=FCG(TEMP,RFA)
*     NOTE 43200=12*3600
      REG=43200.*G*DHO(NC)/VISG
      PRG=VISG*CPG/KG
      HBTO=.230*REG**(-.3)*PRG**(-.667)*G*CPG
      BM=SQRT(3600.*12.*HBTO/(FKM(TEMP)*DS(NC)))
      Z=3.63*BH(NC)*BM
      EM=TANH(Z)/Z
      SMTSBT=18.8*BH(NC)*BT(NC)/DO(NC)
      HTC=EM*SMTSBT*HBTO
      RETURN
      END
```

SUBROUTINE HTPF

HTPF calculates the heat transfer coefficient between the working fluid and the inside surface of a tube with longitudinal fins. It employs the subroutines HT1PB and HT2PB.

NOMENCLATURE -- HTPF

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HTPF are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
DFL	Specific volume of liquid	ft^3/lb
DFV	Specific volume of vapor	ft^3/lb
G	Mass velocity	$lb/in.^2$ sec
HFL	Enthalpy of liquid	Btu/lb
HFV	Enthalpy of vapor	Btu/lb
HTC	Heat transfer coefficient	Btu/sec $in.^2$ °F
NC	Fluid pass number	--
PPF	Pressure of working fluid	$lb/in.^2$
TI	Wall temperature at mid-node of a lump	°F
TTF	Bulk fluid temperature	°F
X	Quality of bulk mass within a lump	--

PROGRAM LISTING -- HTPF

```
      SUBROUTINE HTPF(HTC,NC,G,PPF,TTF,TI,X,DFL,DFV,HFL,HFV)
*     THIS SUBROUTINE CALCULATES THE HEAT TRANSFER COEFFICIENT
*     FROM FLUID INSIDE A TUBE TO THE INSIDE TUBE SURFACE
*     WITH LONGITUDINAL FINS AND FOR EITHER SINGLE TO TWO PHASE
*     FLOW AS INDICATED BY NPH.
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      GO TO (10,20,10),NPH
   10 CALL HT1PH(HBTI,NC,G,PPF,TTF)
      GO TO 30
   20 CALL HT2PH(HBTI,NC,G,TTF,TI,X,PPF,DFL,DFV,HFL,HFV)
*     NOTE 86400=2*12*3600
   30 BTI=SQRT(86400.*HBTI/(FKS(TI)*FTI(NC)))
      ETA=BTI*FHI(NC)
      ETA=TANH(ETA)/ETA
      SESETI=FNI(NC)*(2.*FHI(NC)+FTI(NC))/
     2       (3.1416*DI(NC)+FNI(NC)*2.*FHI(NC))
      SETSBT=1.+FNI(NC)*2.*FHI(NC)/(3.1416*DI(NC))
      EPS=ETA*SESETI+1./SETSBT
      HTC=EPS*SETSBT*HBTI
*     NOTE HBTI ALREADY INCLUDES FACTOR 43200=12*3600
      RETURN
      END
```

Section 7

CONDENSER MODEL

MAIN PROGRAM -- COND

The condenser model is titled COND. The model employs the following subroutines:

DISTR
CGEOMC
STEPSC
ITERAT
SATP
PROP
SUPPT
PROPST
PDROP1
PDROP2
PDROPA
INTSTE
PHASE
HT1PB
HT2PC
HTAC
FCWL
FDWL
FKWL
FVWL
FYWL
FCWV
FDWV
FKWV
FVWV
FCA
FDA
FKA
FVA
FCG
FDG
FKG
FVG
FCMC
FKC
FRMC
FCMS
FKS
FRMS
FKM

Figure 2 illustrates the links between the various subroutines required for COND.

The input parameter, FRAC, is the ratio of actual step size to stability step size. To avoid numerical instability, its value should be less than unity. FRAC has been set at 0.5 in the present program.

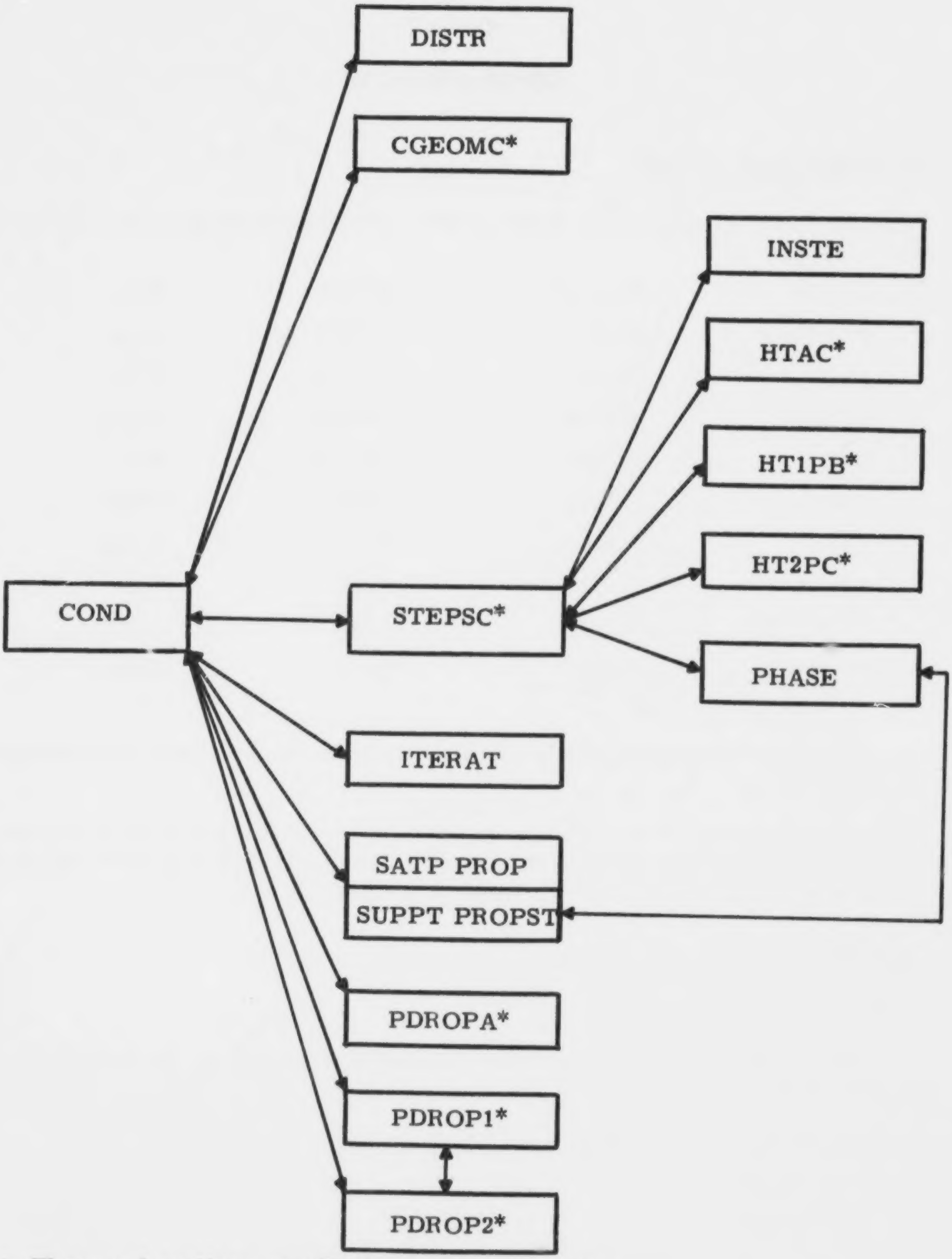
NOMENCLATURE -- COND

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of COND are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
JS	Variable to denote cumulative number of timesteps	--
MGI	Mass flow rate of gas at inlet	lb/sec


DISTR
CGEOMC*
INSTE
HTAC*
HT1PB*
HT2PC*
COND
STEPSC*
PHASE
ITERAT
SATP PROP
SUPPT PROPST
PDROPA*
PDROP1*
PDROP2*

* These subroutines use fluid or metal properties.

Figure 2. Links Between Subroutines Used by COND

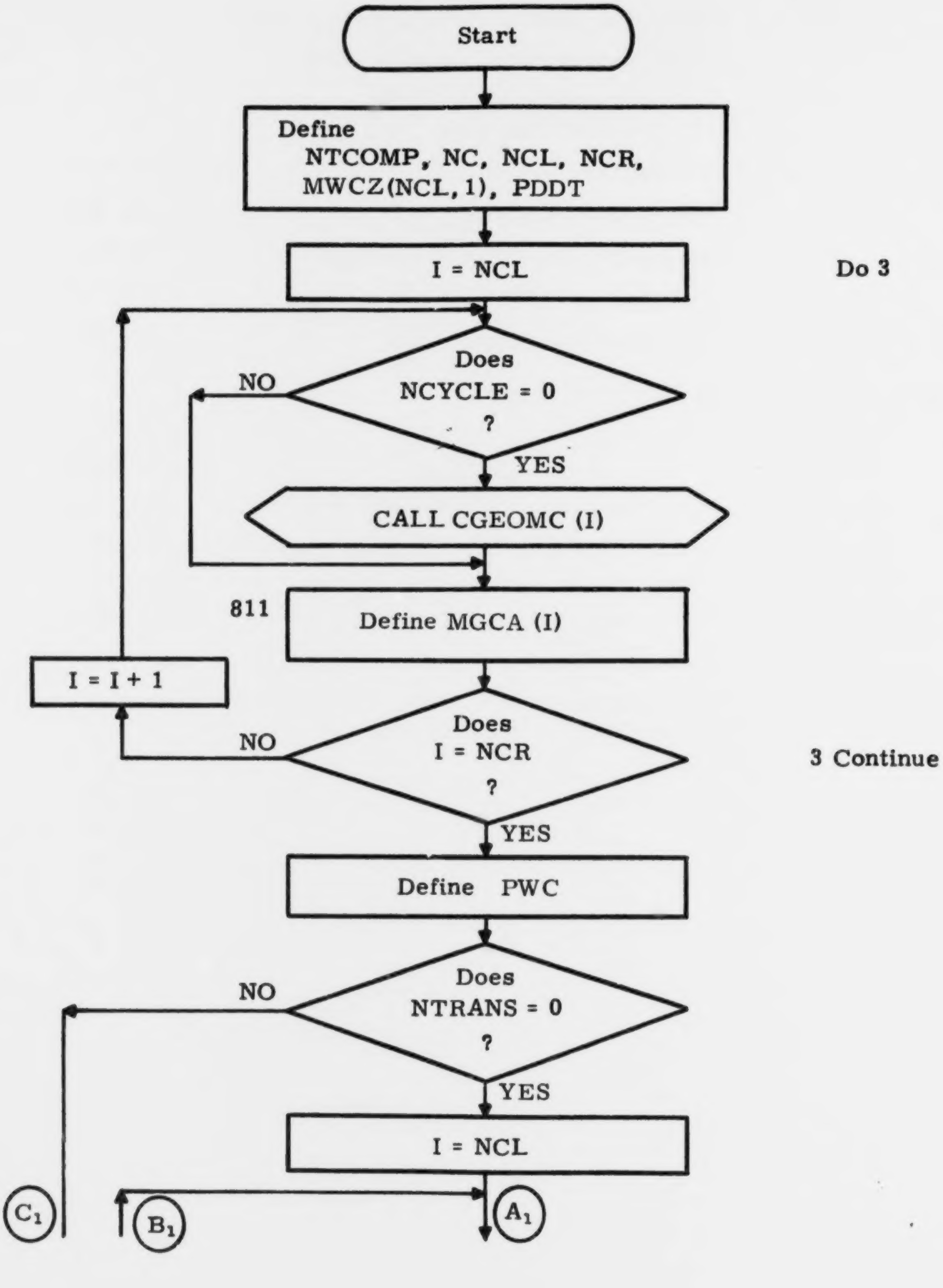
FORTRAN Variable	Definition	Units
MWE	Mass flow rate of working fluid at exit	lb/sec
NST	Logic variable for transient start 0 - steady-state case 1 - transient case	--
PGCE	Pressure of gas at exit	$lb/in.^2$
PGCI	Pressure of gas at inlet	$lb/in.^2$
PWCE	Pressure of working fluid at exit	$lb/in.^2$
PWCI	Pressure of working fluid at inlet	$lb/in.^2$
TGCI	Temperature of gas at inlet	°F

Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
MGCZ(I)	Gas mass flow rate for fluid pass I	lb/sec
MWCZ(I, J)	Fluid mass flow rate for fluid pass I at mode J	lb/sec
PWC	Fluid pressure	$lb/in.^2$

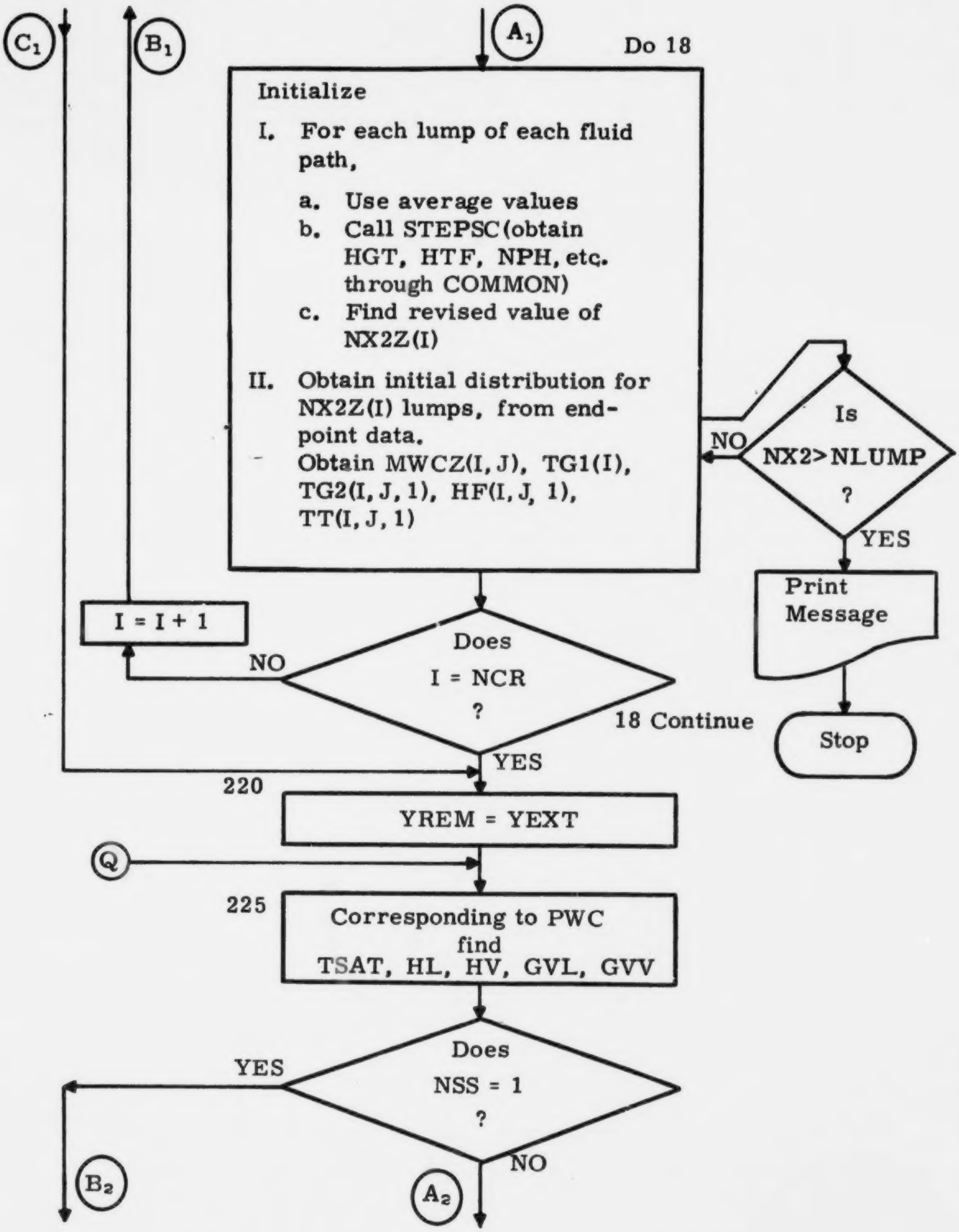
Note: For the remainder of these variables, see "Other Selected FORTRAN Variables" for VAPORG, in Section 6.

FLOW DIAGRAM -- COND



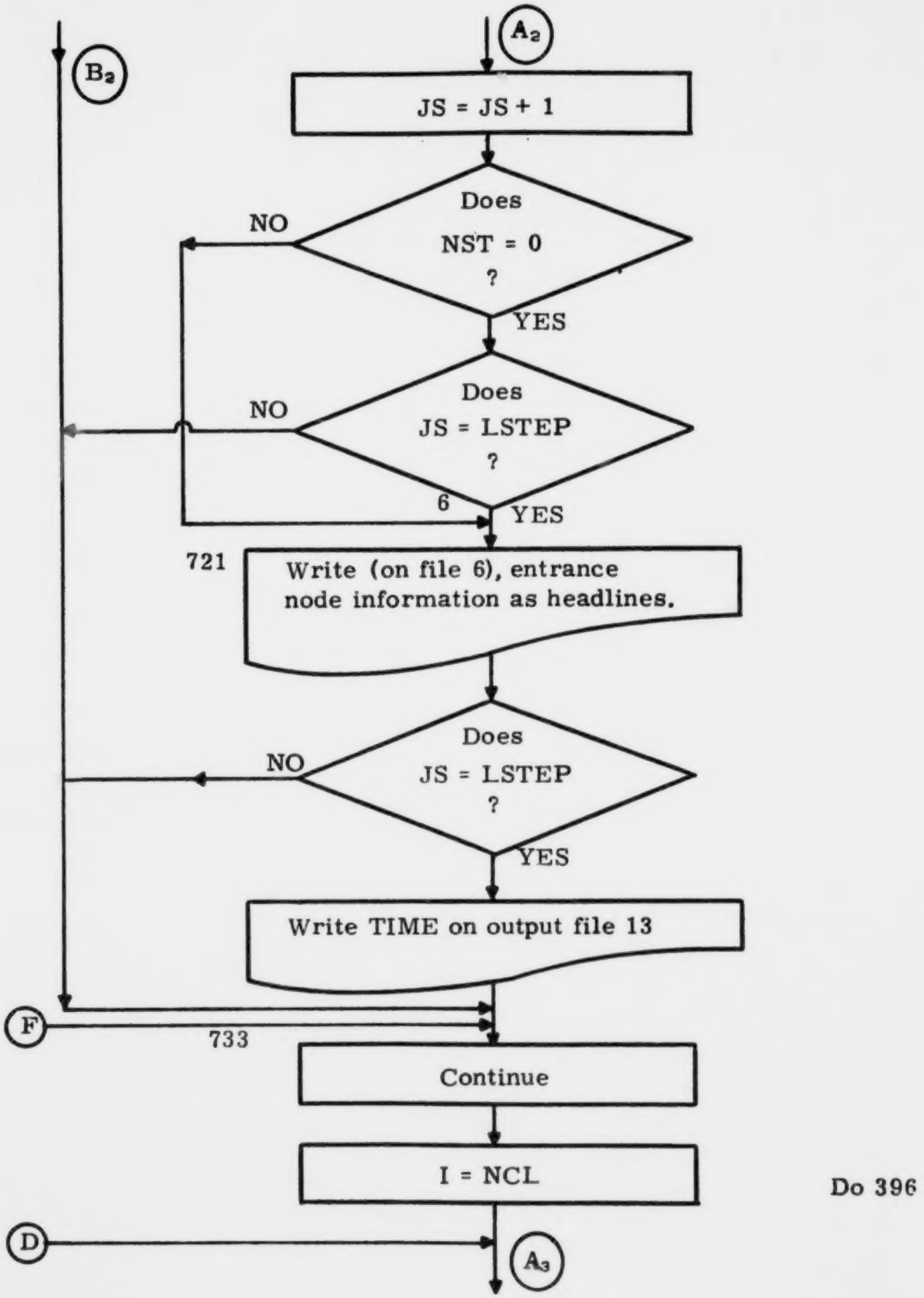
Start
Define
NTCOMP, NC, NCL, NCR,
MWCZ(NCL, 1), PDDT
I = NCL
Do 3
Does
NCYCLE = 0
?
NO
YES
CALL CGEOMC (I)
811
Define MGCA (I)
I = I + 1
Does
I = NCR
?
NO
YES
3 Continue
Define PWC
Does
NTRANS = 0
?
NO
YES
I = NCL
C_1
B_1
A_1

FLOW DIAGRAM -- COND (Cont'd)

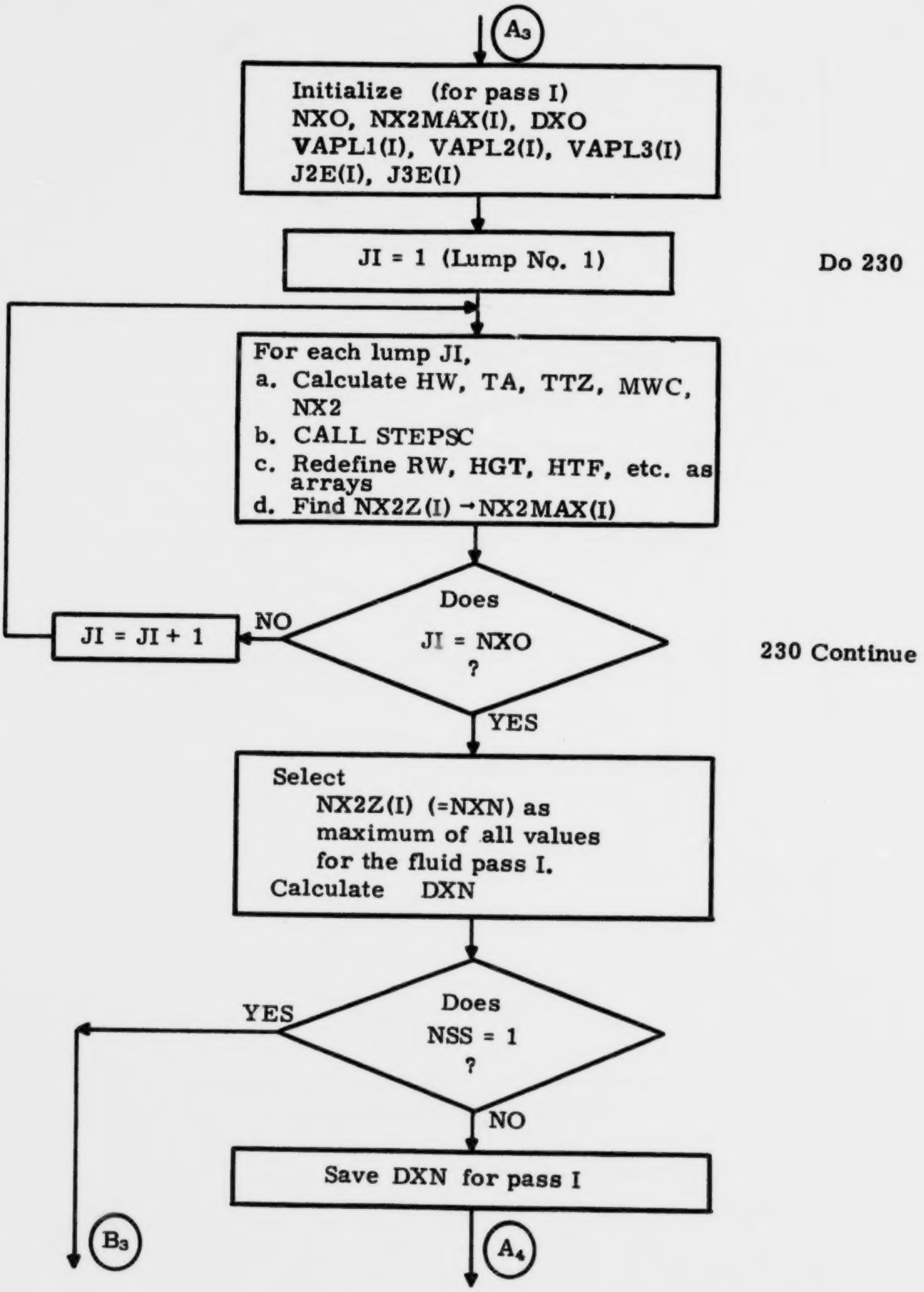


C_1
B_1
A_1
Do 18
Initialize
I. For each lump of each fluid path,
a. Use average values
b. Call STEPSC (obtain HGT, HTF, NPH, etc. through COMMON)
c. Find revised value of NX2Z(I)
II. Obtain initial distribution for NX2Z(I) lumps, from end-point data.
Obtain MWCZ(I, J), TG1(I), TG2(I, J, 1), HF(I, J, 1), TT(I, J, 1)
NO
Is NX2>NLUMP ?
YES
Print Message
Stop
I = I + 1
NO
Does I = NCR ?
18 Continue
YES
220
YREM = YEXT
Q
225
Corresponding to PWC find TSAT, HL, HV, GVL, GVV
YES
Does NSS = 1 ?
NO
B_2
A_2

FLOW DIAGRAM -- COND (Cont'd)

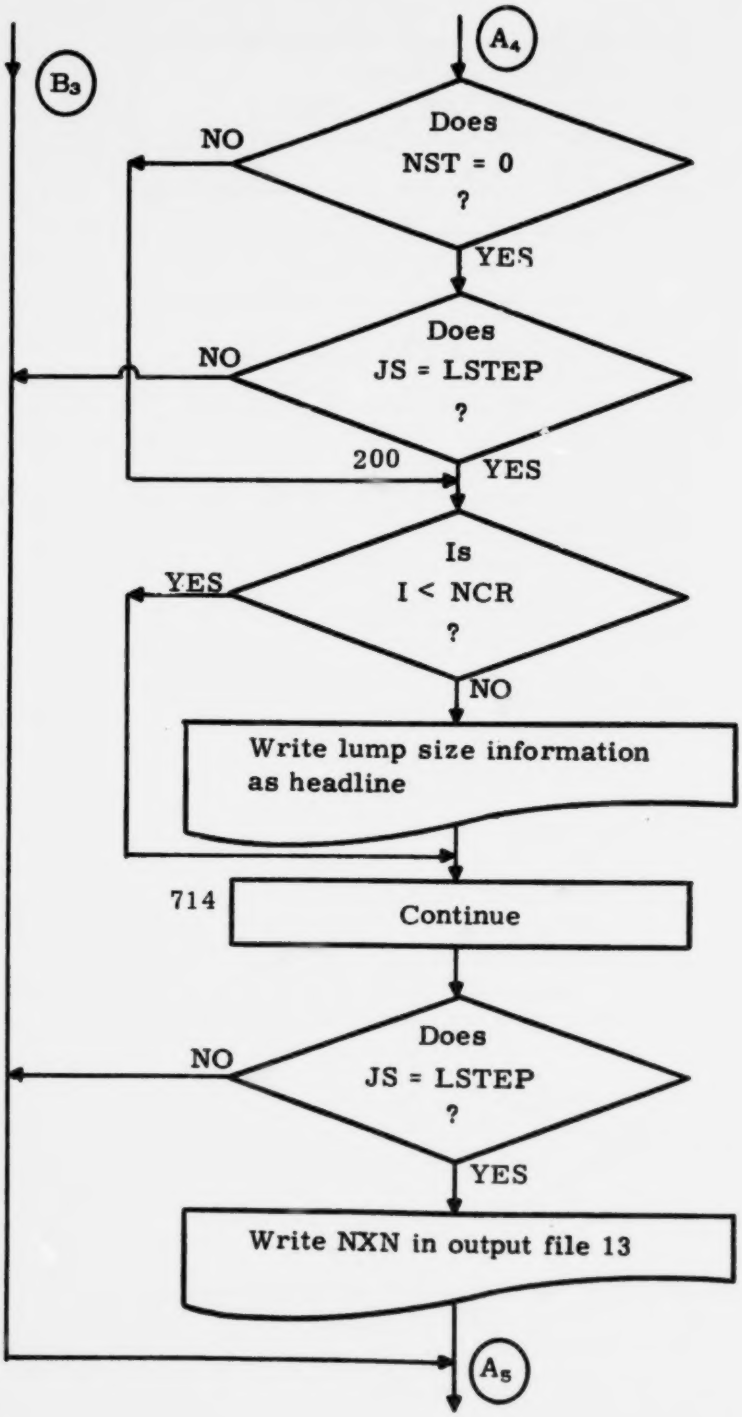

A2
B2
JS = JS + 1
Does
NST = 0
?
NO
YES
Does
JS = LSTEP
?
NO
6
YES
721
Write (on file 6), entrance node information as headlines.
Does
JS = LSTEP
?
NO
YES
Write TIME on output file 13
F
733
Continue
I = NCL
Do 396
D
A3

FLOW DIAGRAM -- COND (Cont'd)

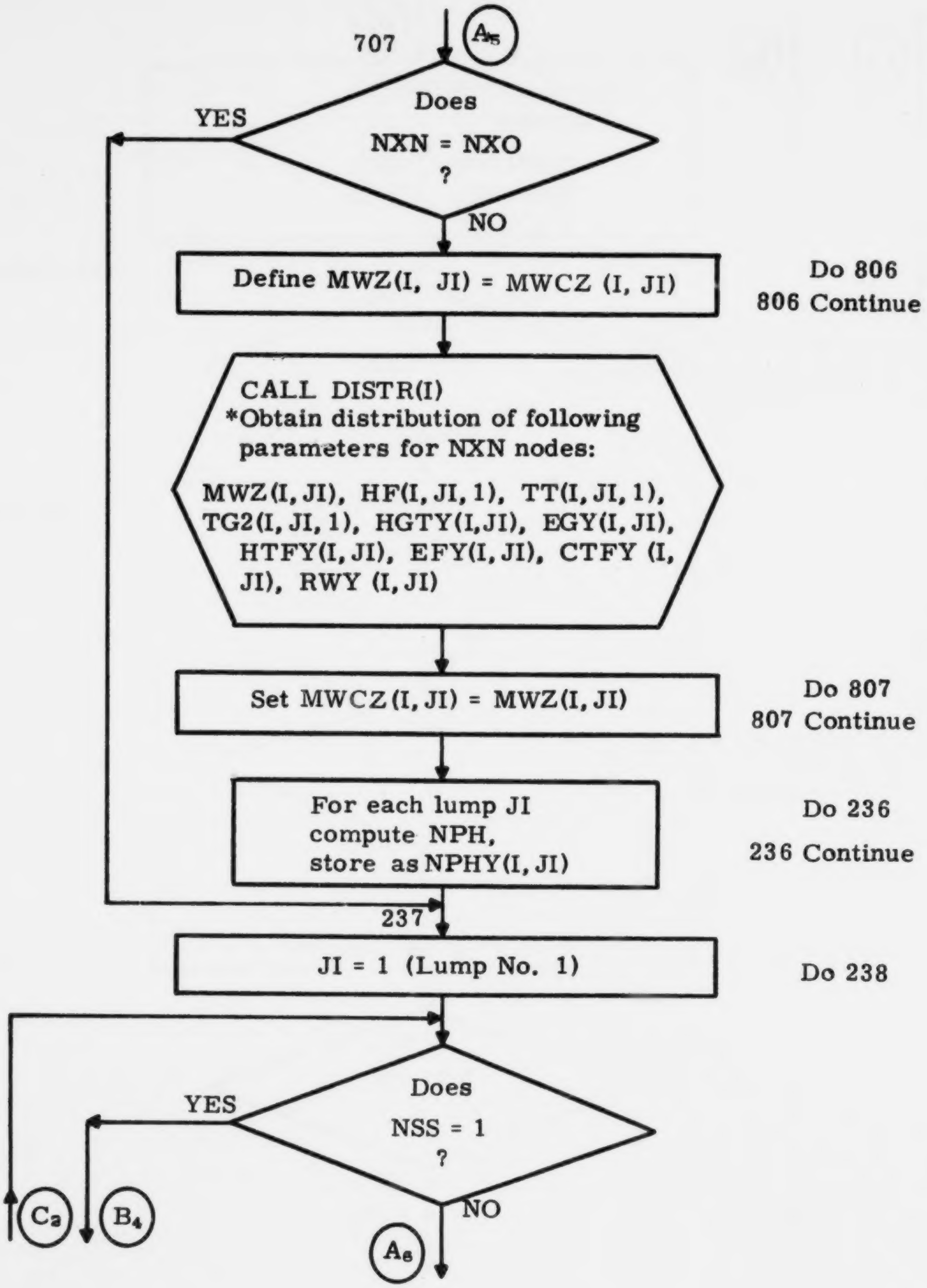


A3
Initialize (for pass I)
NXO, NX2MAX(I), DXO
VAPL1(I), VAPL2(I), VAPL3(I)
J2E(I), J3E(I)
JI = 1 (Lump No. 1)
Do 230
For each lump JI,
a. Calculate HW, TA, TTZ, MWC, NX2
b. CALL STEPSC
c. Redefine RW, HGT, HTF, etc. as arrays
d. Find NX2Z(I) → NX2MAX(I)
Does JI = NXO ?
NO
JI = JI + 1
230 Continue
YES
Select NX2Z(I) (=NXN) as maximum of all values for the fluid pass I.
Calculate DXN
Does NSS = 1 ?
YES
NO
Save DXN for pass I
B3
A4

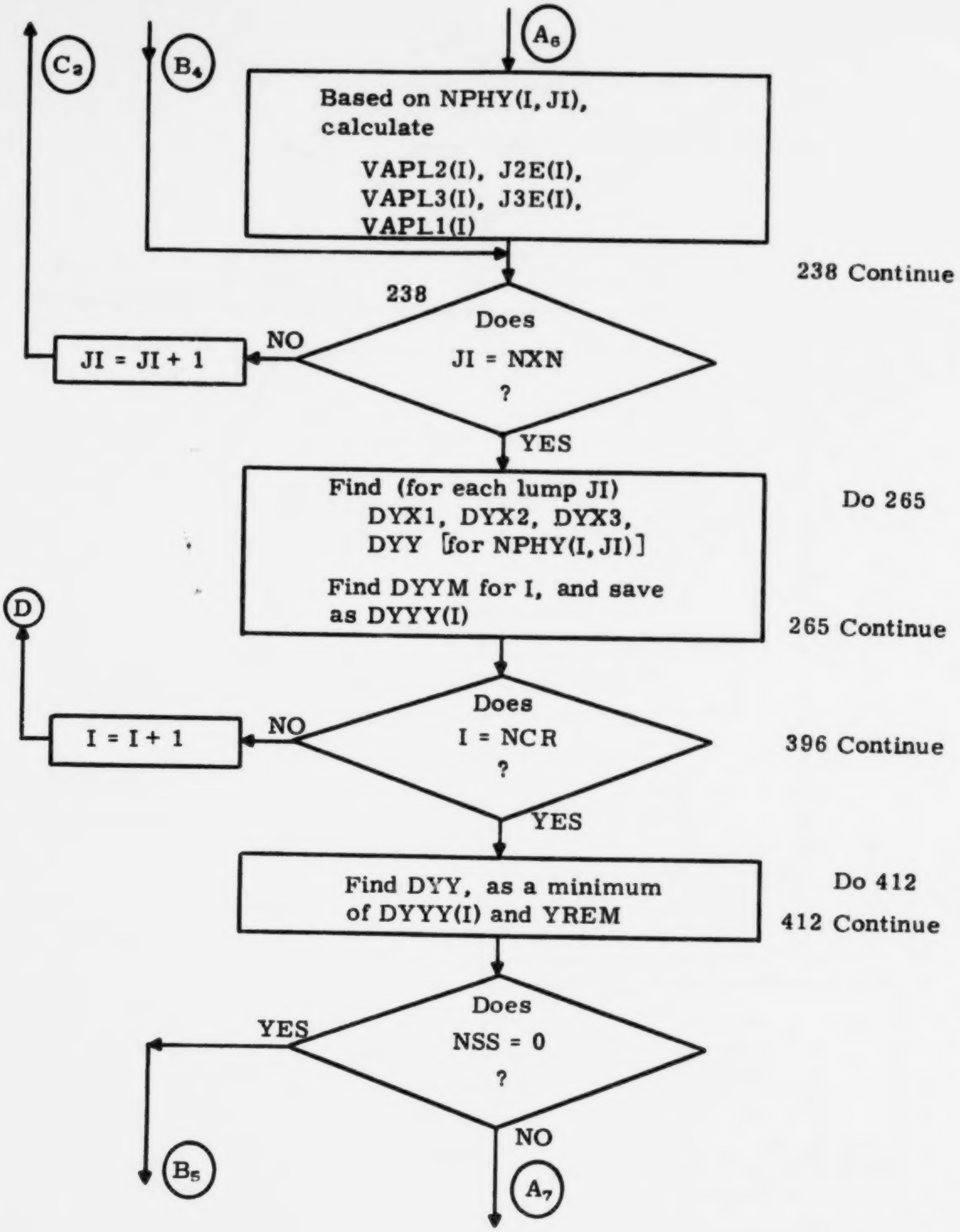
FLOW DIAGRAM -- COND (Cont'd)


A₄
B₃
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
200
Is I < NCR ?
YES
NO
Write lump size information as headline
714
Continue
Does JS = LSTEP ?
NO
YES
Write NXN in output file 13
A₅

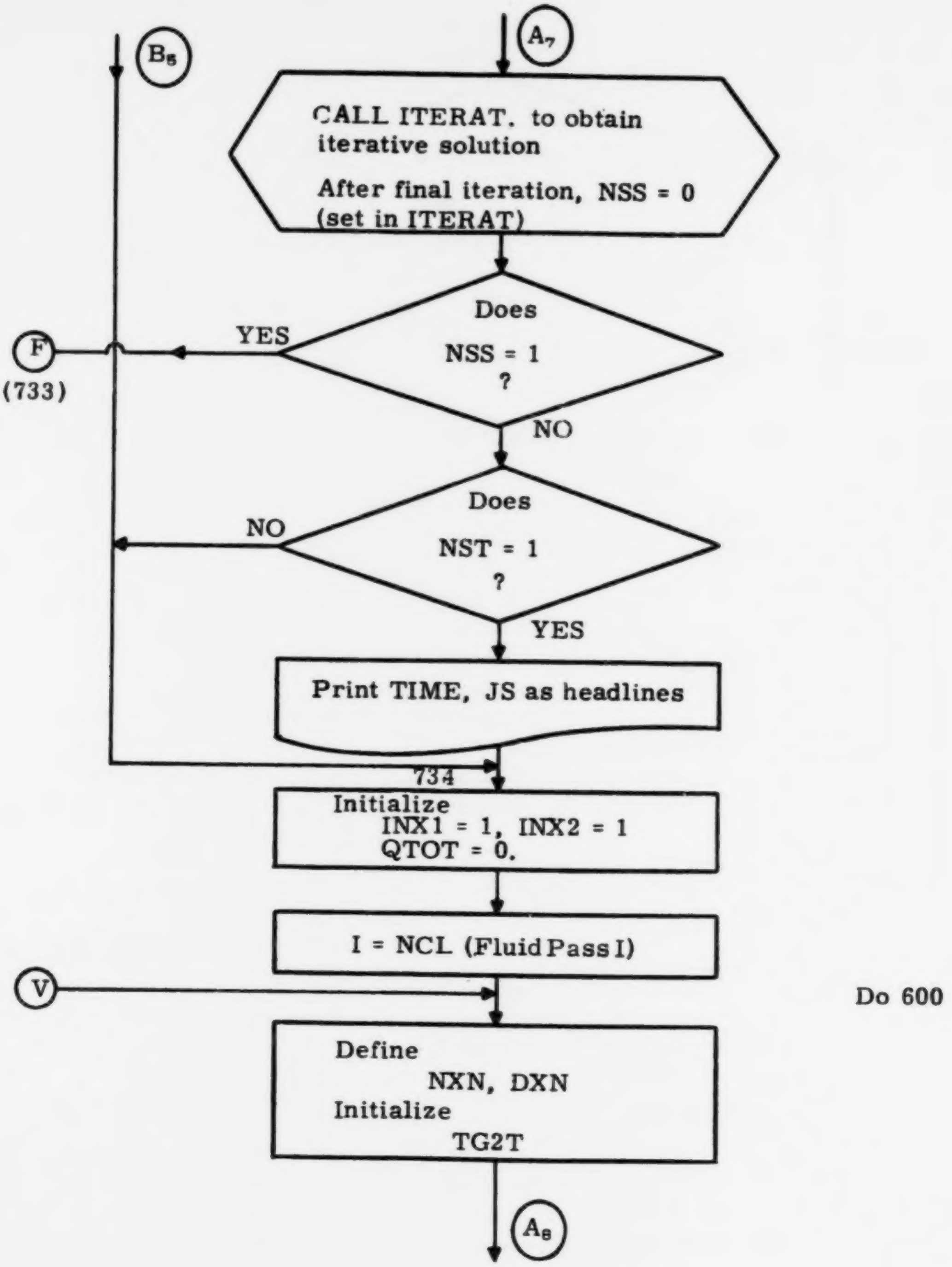
FLOW DIAGRAM -- COND (Cont'd)


707
A_5
Does NXN = NXO ?
YES
NO
Define MWZ(I, JI) = MWCZ (I, JI)
Do 806
806 Continue
CALL DISTR(I)
*Obtain distribution of following parameters for NXN nodes:
MWZ(I, JI), HF(I, JI, 1), TT(I, JI, 1), TG2(I, JI, 1), HGTY(I,JI), EGY(I, JI), HTFY(I, JI), EFY(I, JI), CTFY (I, JI), RWY (I, JI)
Set MWCZ(I, JI) = MWZ(I, JI)
Do 807
807 Continue
For each lump JI compute NPH, store as NPHY(I, JI)
Do 236
236 Continue
237
JI = 1 (Lump No. 1)
Do 238
Does NSS = 1 ?
YES
NO
C_2
B_4
A_6

FLOW DIAGRAM -- COND (Cont'd)

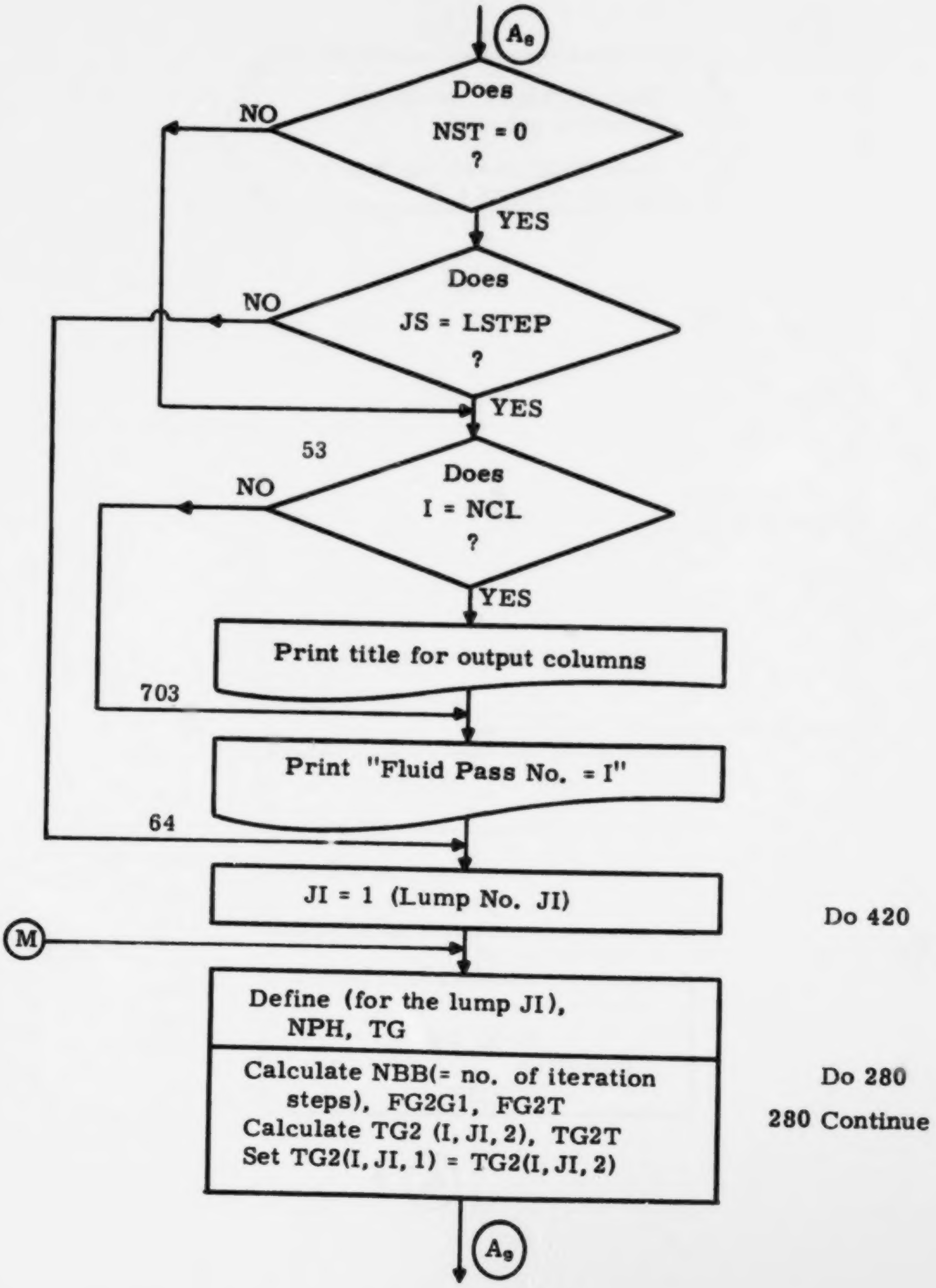

A₆
C₂
B₄
Based on NPHY(I, JI), calculate VAPL2(I), J2E(I), VAPL3(I), J3E(I), VAPL1(I)
238 Continue
238
Does JI = NXN ?
NO
JI = JI + 1
YES
Find (for each lump JI) DYX1, DYX2, DYX3, DYY [for NPHY(I, JI)]
Find DYYM for I, and save as DYYY(I)
Do 265
265 Continue
D
Does I = NCR ?
NO
I = I + 1
396 Continue
YES
Find DYY, as a minimum of DYYY(I) and YREM
Do 412
412 Continue
Does NSS = 0 ?
YES
NO
B₅
A₇

FLOW DIAGRAM -- COND (Cont'd)

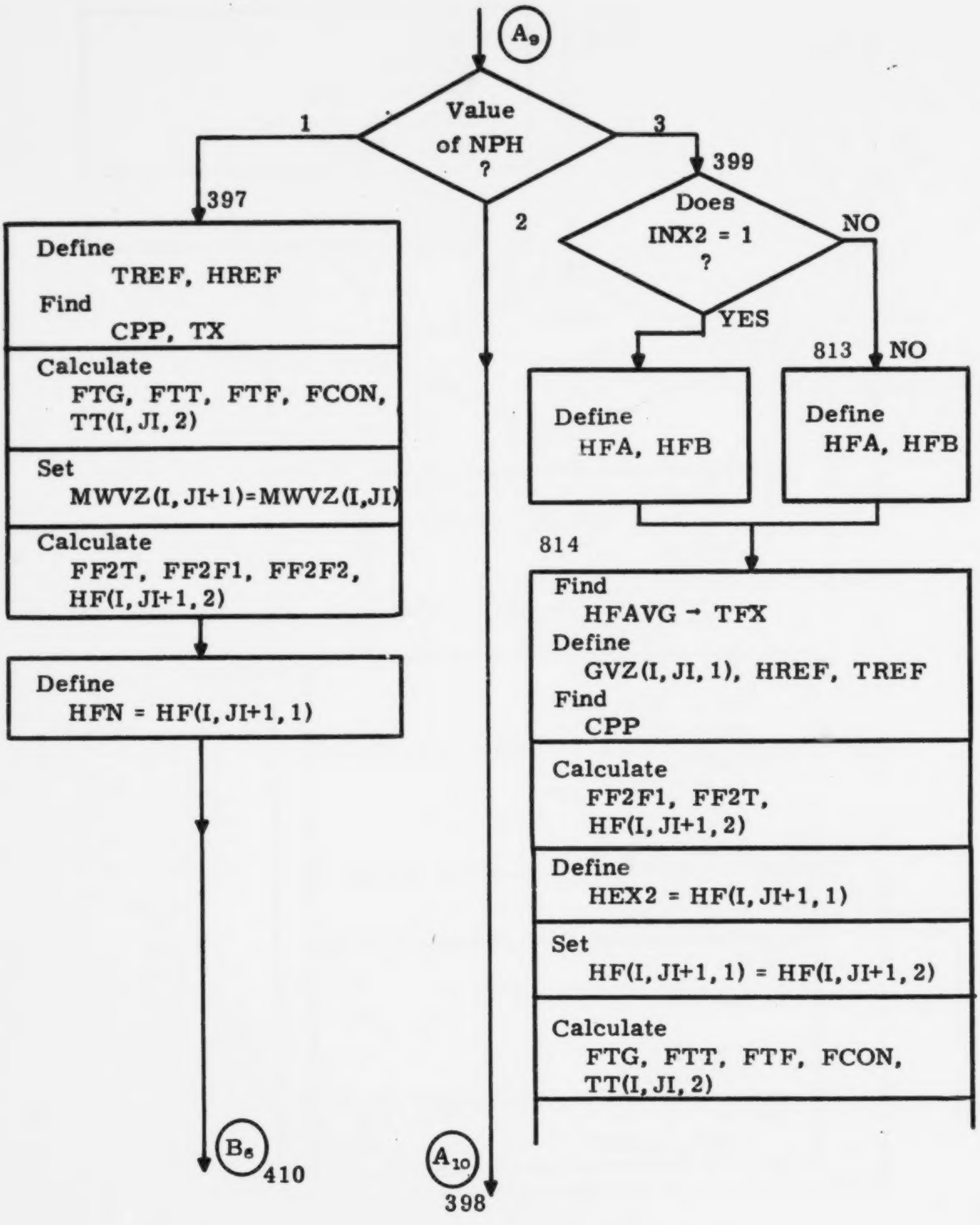


A7
B8
CALL ITERAT. to obtain iterative solution
After final iteration, NSS = 0 (set in ITERAT)
Does NSS = 1 ?
YES
F
(733)
NO
Does NST = 1 ?
NO
YES
Print TIME, JS as headlines
734
Initialize INX1 = 1, INX2 = 1 QTOT = 0.
I = NCL (Fluid Pass I)
V
Do 600
Define NXN, DXN
Initialize TG2T
A8

FLOW DIAGRAM -- COND (Cont'd)

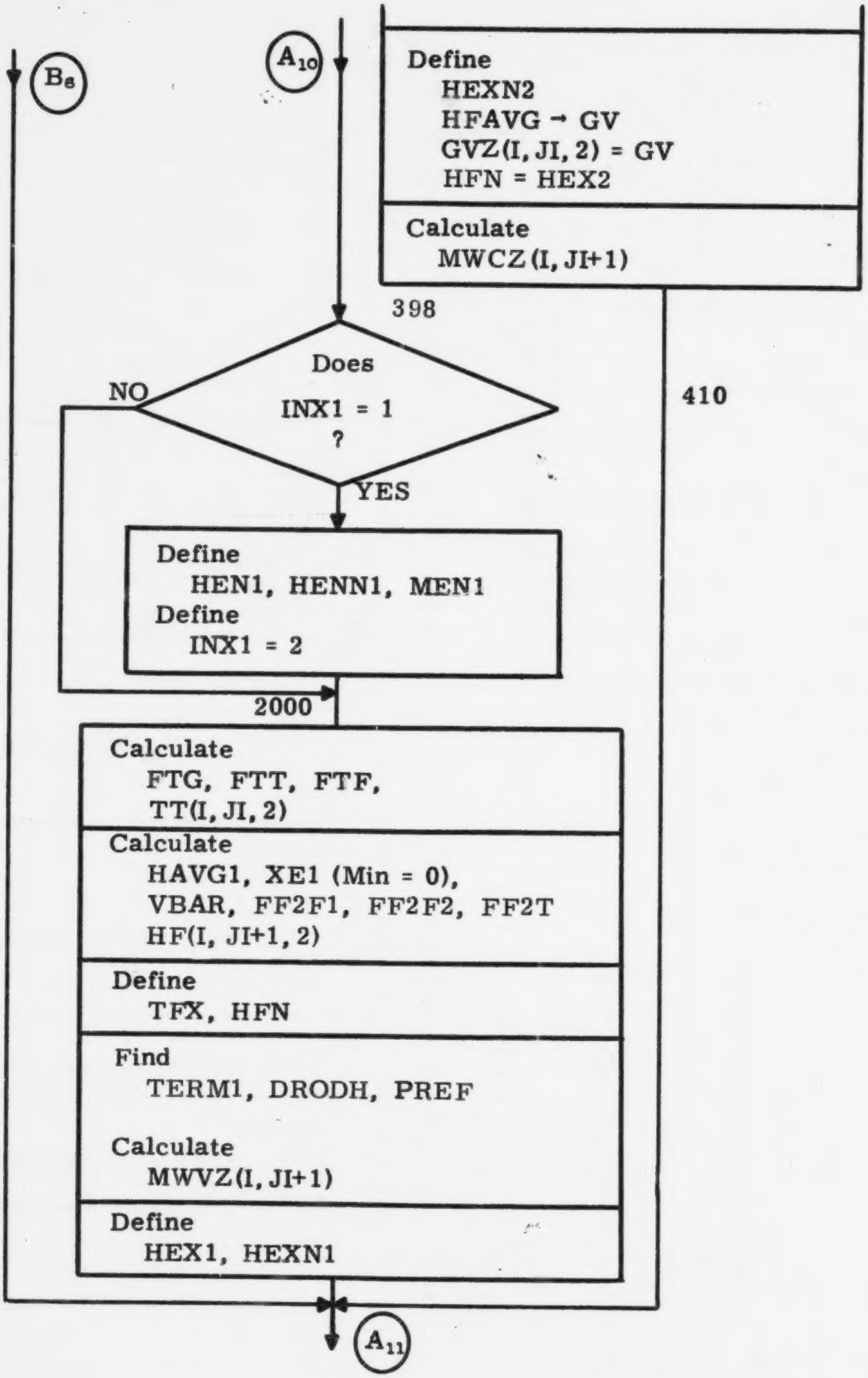

A_8
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
53
Does I = NCL ?
NO
YES
Print title for output columns
703
Print "Fluid Pass No. = I"
64
JI = 1 (Lump No. JI)
Do 420
M
Define (for the lump JI), NPH, TG
Calculate NBB(= no. of iteration steps), FG2G1, FG2T
Calculate TG2 (I, JI, 2), TG2T
Set TG2(I, JI, 1) = TG2(I, JI, 2)
Do 280
280 Continue
A_9

FLOW DIAGRAM -- COND (Cont'd)

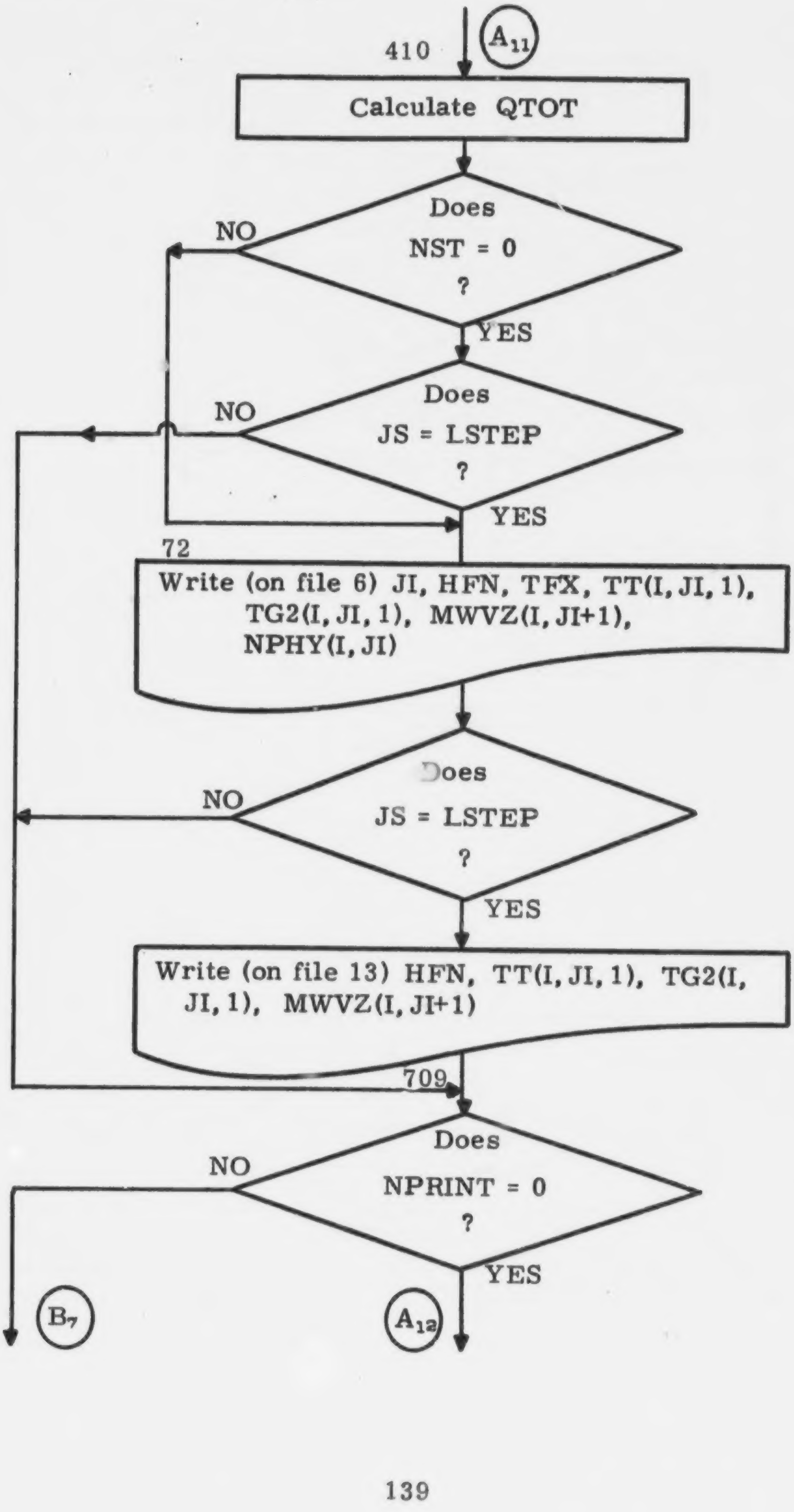


A_9
Value of NPH ?
1
2
3
397
Define TREF, HREF
Find CPP, TX
Calculate FTG, FTT, FTF, FCON, TT(I, JI, 2)
Set MWVZ(I, JI+1)=MWVZ(I,JI)
Calculate FF2T, FF2F1, FF2F2, HF(I, JI+1, 2)
Define HFN = HF(I, JI+1, 1)
B_8
410
A_{10}
398
399
Does INX2 = 1 ?
YES
NO
813
NO
Define HFA, HFB
Define HFA, HFB
814
Find HFAVG → TFX
Define GVZ(I, JI, 1), HREF, TREF
Find CPP
Calculate FF2F1, FF2T, HF(I, JI+1, 2)
Define HEX2 = HF(I, JI+1, 1)
Set HF(I, JI+1, 1) = HF(I, JI+1, 2)
Calculate FTG, FTT, FTF, FCON, TT(I, JI, 2)

FLOW DIAGRAM -- COND (Cont'd)

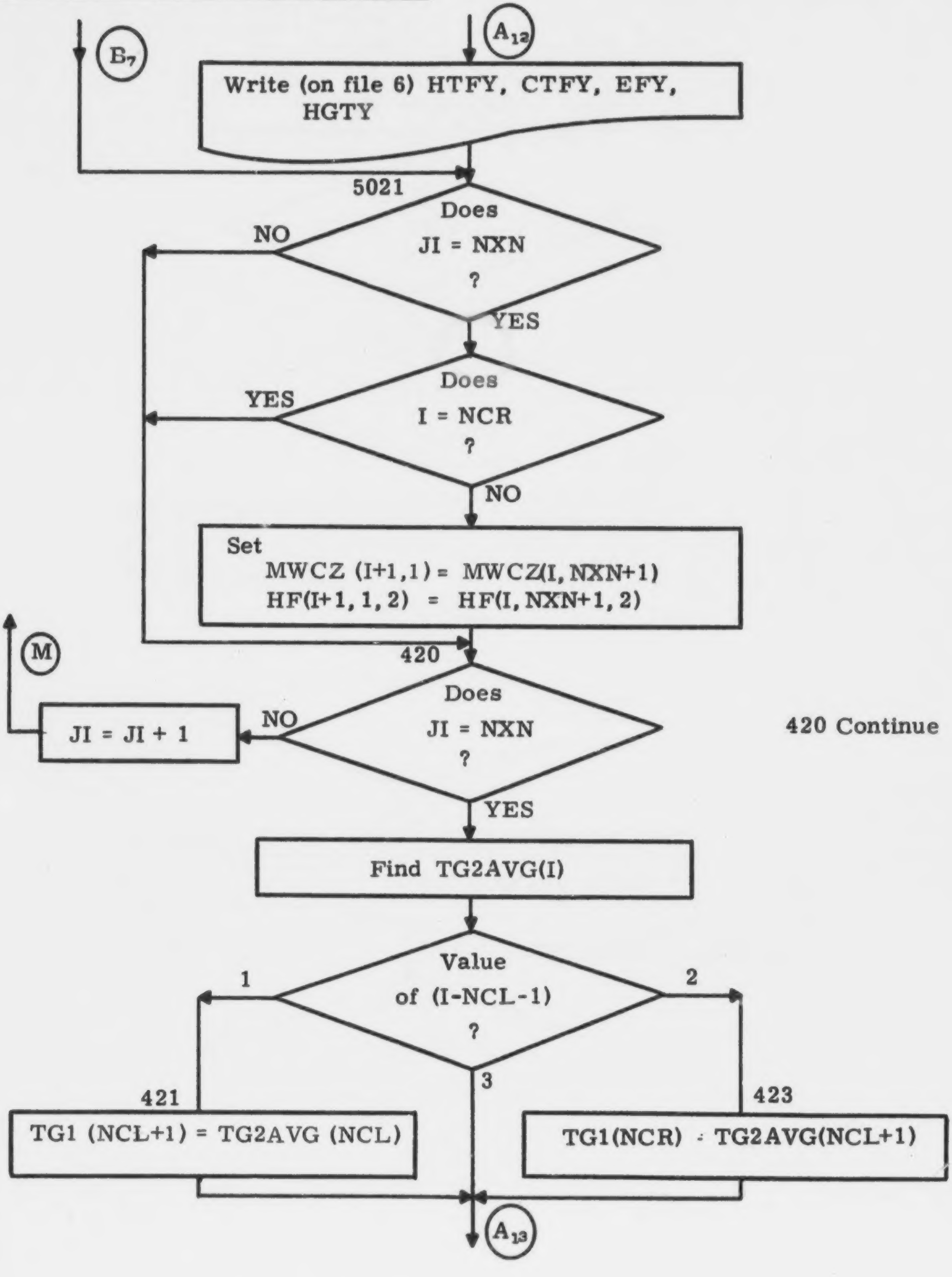

B8
A10
Define
HEXN2
HFAVG → GV
GVZ(I, JI, 2) = GV
HFN = HEX2
Calculate
MWCZ(I, JI+1)
398
Does
INX1 = 1
?
NO
YES
410
Define
HEN1, HENN1, MEN1
Define
INX1 = 2
2000
Calculate
FTG, FTT, FTF,
TT(I, JI, 2)
Calculate
HAVG1, XE1 (Min = 0),
VBAR, FF2F1, FF2F2, FF2T
HF(I, JI+1, 2)
Define
TFX, HFN
Find
TERM1, DRODH, PREF
Calculate
MWVZ(I, JI+1)
Define
HEX1, HEXN1
A11

FLOW DIAGRAM -- COND (Cont'd)



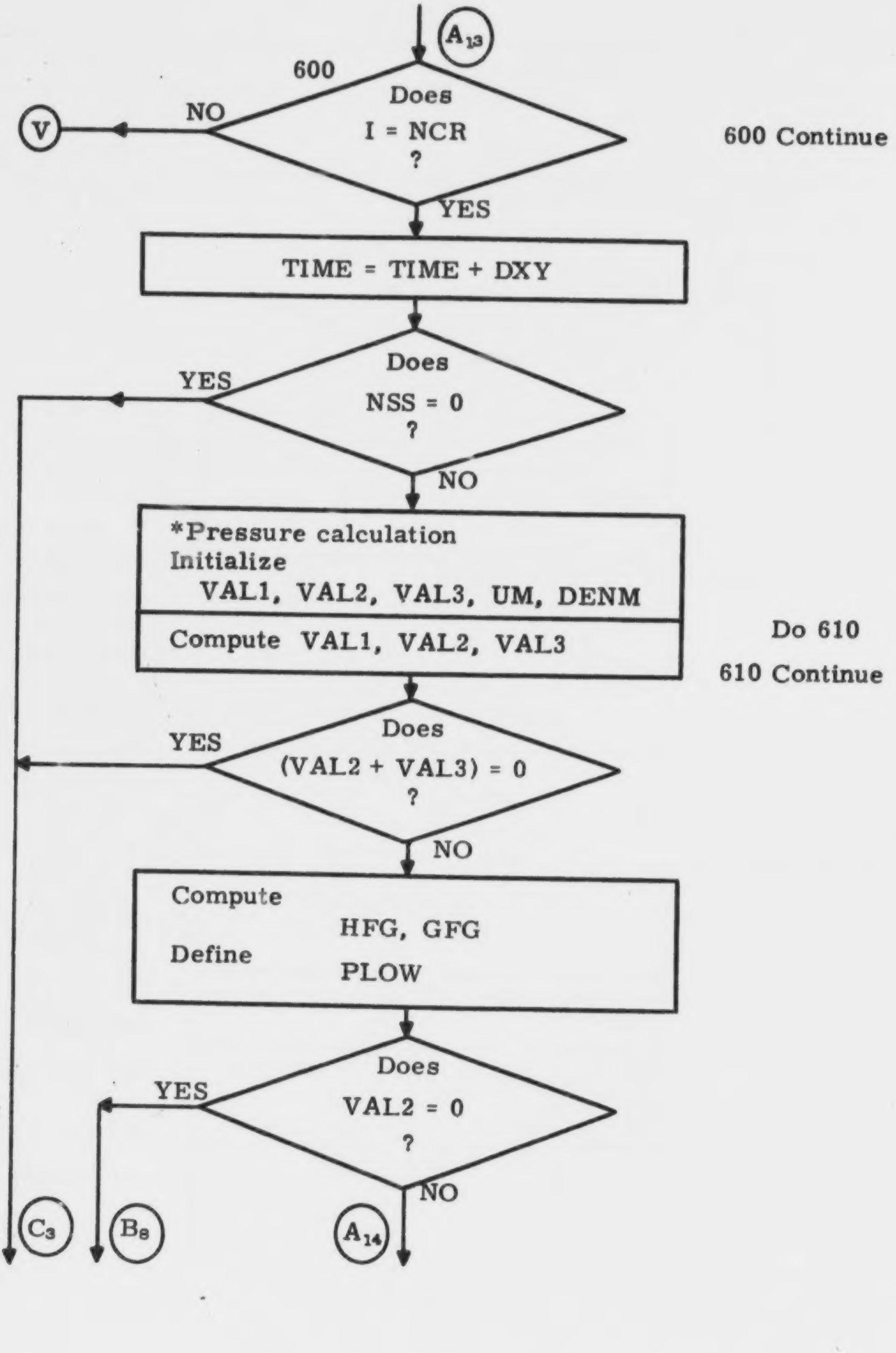
A_{11}
410
Calculate QTOT
NO
Does NST = 0 ?
YES
NO
Does JS = LSTEP ?
YES
72
Write (on file 6) JI, HFN, TFX, TT(I, JI, 1), TG2(I, JI, 1), MWVZ(I, JI+1), NPHY(I, JI)
NO
Does JS = LSTEP ?
YES
Write (on file 13) HFN, TT(I, JI, 1), TG2(I, JI, 1), MWVZ(I, JI+1)
709
NO
Does NPRINT = 0 ?
YES
B_7
A_{12}

FLOW DIAGRAM -- COND (Cont'd)



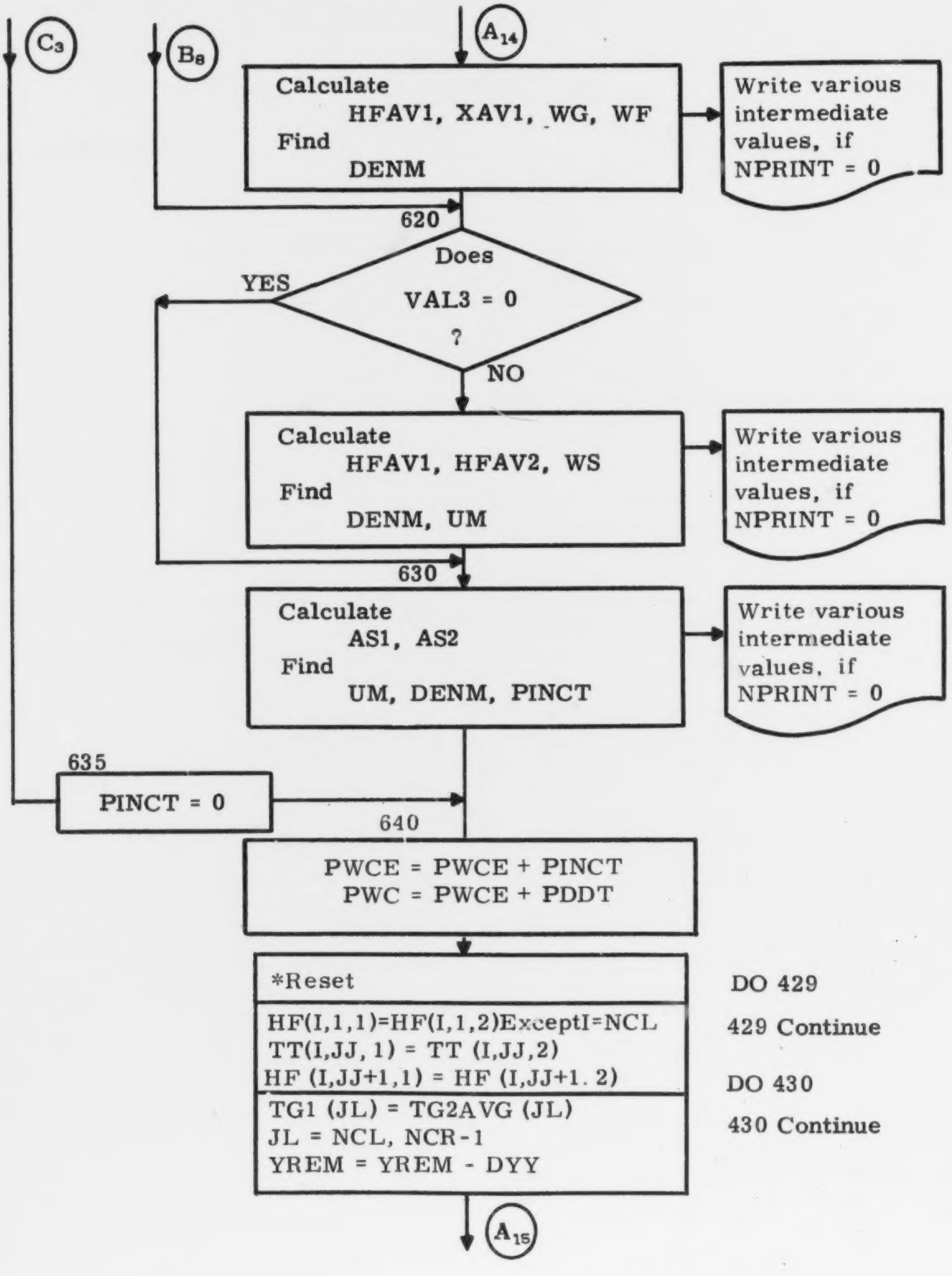
B7
A12
Write (on file 6) HTFY, CTFY, EFY, HGTY
5021
Does JI = NXN ?
NO
YES
Does I = NCR ?
YES
NO
Set
MWCZ (I+1,1) = MWCZ(I, NXN+1)
HF(I+1, 1, 2) = HF(I, NXN+1, 2)
M
420
JI = JI + 1
NO
Does JI = NXN ?
420 Continue
YES
Find TG2AVG(I)
Value of (I-NCL-1) ?
1
2
3
421
TG1 (NCL+1) = TG2AVG (NCL)
423
TG1(NCR) = TG2AVG(NCL+1)
A13

FLOW DIAGRAM -- COND (Cont'd)

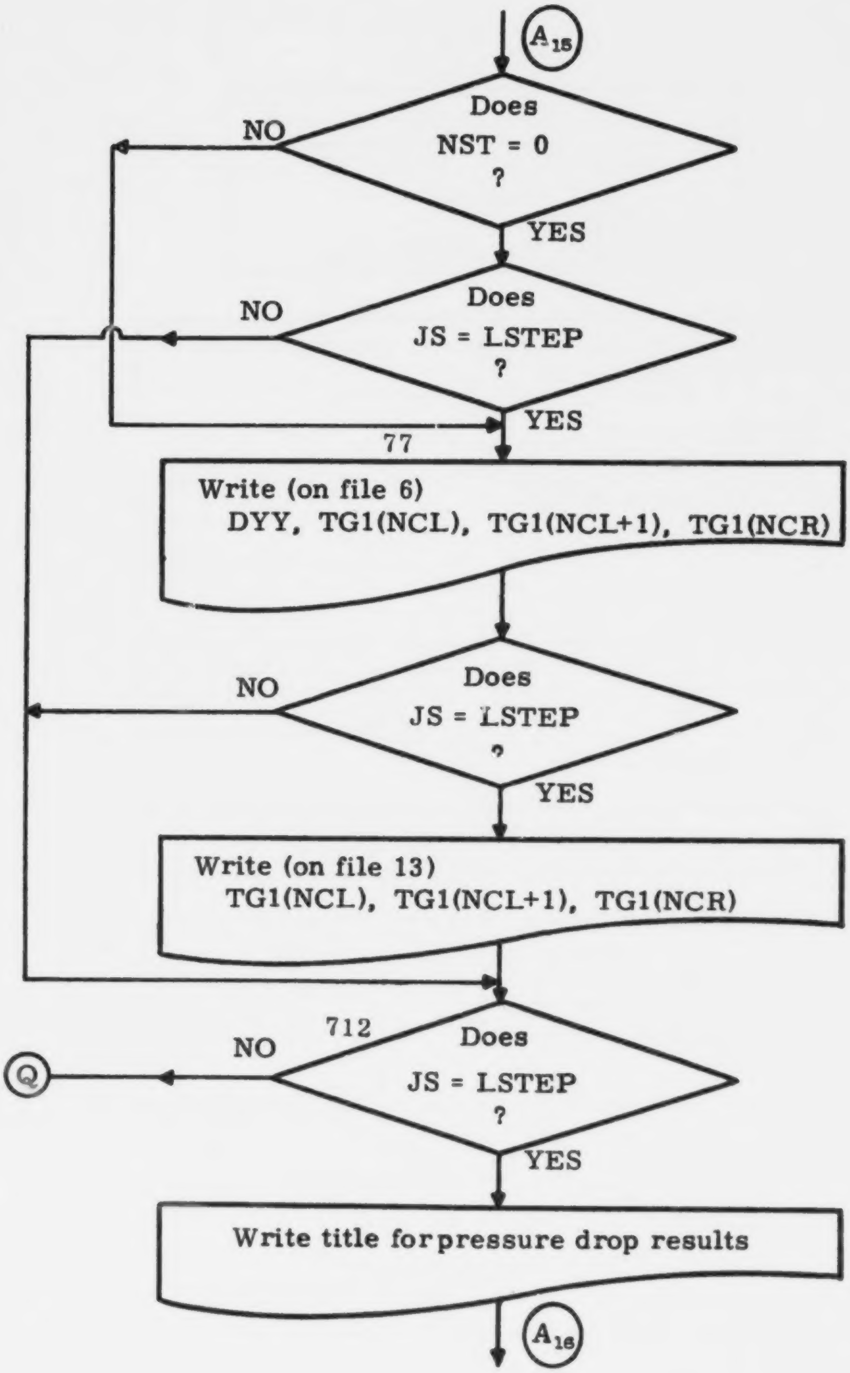


A_{13}
600
Does
I = NCR
?
NO
YES
V
600 Continue
TIME = TIME + DXY
Does
NSS = 0
?
YES
NO
*Pressure calculation
Initialize
VAL1, VAL2, VAL3, UM, DENM
Compute VAL1, VAL2, VAL3
Do 610
610 Continue
Does
(VAL2 + VAL3) = 0
?
YES
NO
Compute
Define
HFG, GFG
PLOW
Does
VAL2 = 0
?
YES
NO
C_3
B_8
A_{14}

FLOW DIAGRAM -- COND (Cont'd)

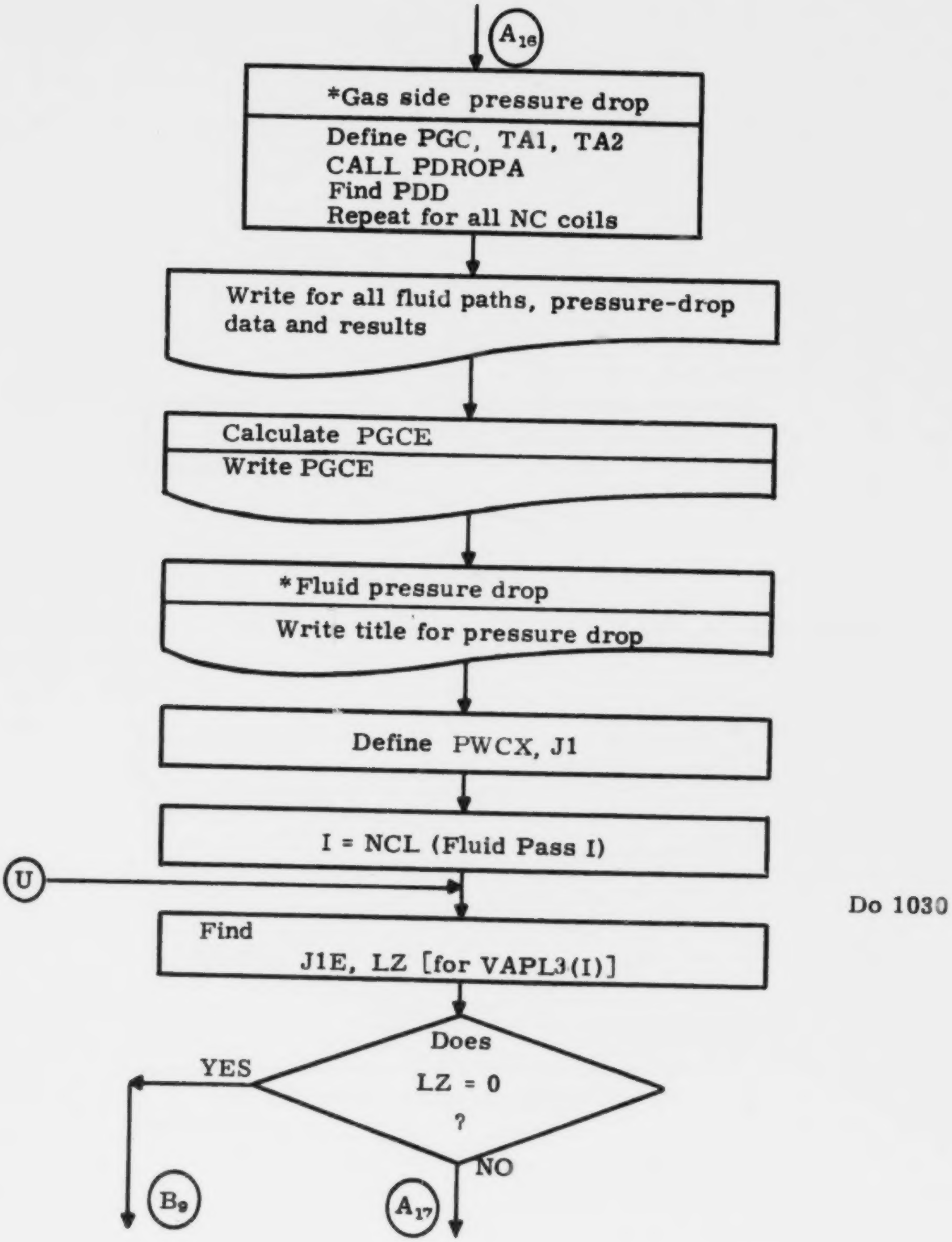

C3
B8
A14
Calculate
HFAV1, XAV1, WG, WF
Find
DENM
Write various intermediate values, if NPRINT = 0
620
Does
VAL3 = 0
?
YES
NO
Calculate
HFAV1, HFAV2, WS
Find
DENM, UM
Write various intermediate values, if NPRINT = 0
630
Calculate
AS1, AS2
Find
UM, DENM, PINCT
Write various intermediate values, if NPRINT = 0
635
PINCT = 0
640
PWCE = PWCE + PINCT
PWC = PWCE + PDDT
*Reset
HF(I,1,1)=HF(I,1,2)ExceptI=NCL
TT(I,JJ, 1) = TT (I,JJ,2)
HF (I,JJ+1,1) = HF (I,JJ+1. 2)
TG1 (JL) = TG2AVG (JL)
JL = NCL, NCR-1
YREM = YREM - DYY
DO 429
429 Continue
DO 430
430 Continue
A15

FLOW DIAGRAM -- COND (Cont'd)

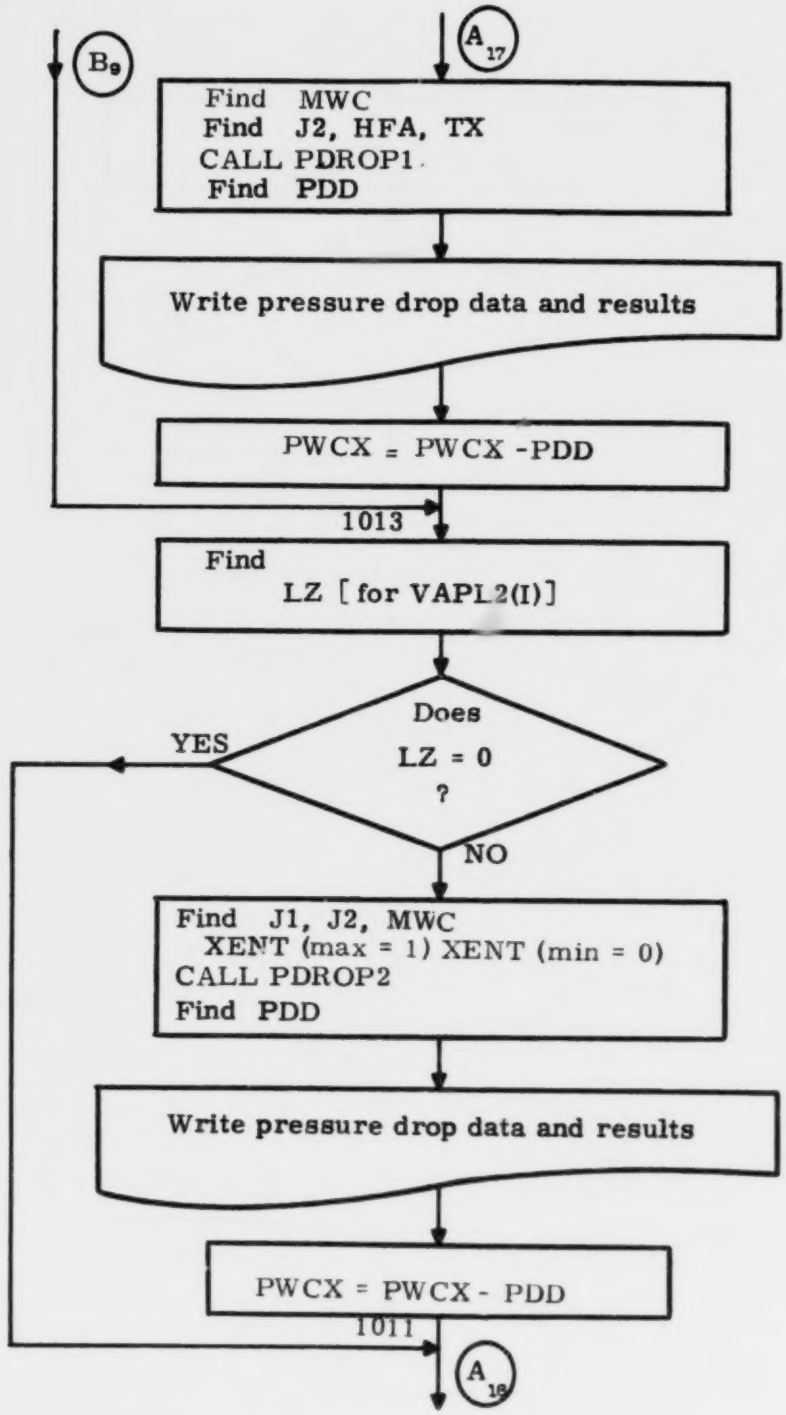


A_{15}
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
77
Write (on file 6)
DYY, TG1(NCL), TG1(NCL+1), TG1(NCR)
Does JS = LSTEP ?
NO
YES
Write (on file 13)
TG1(NCL), TG1(NCL+1), TG1(NCR)
712
Does JS = LSTEP ?
NO
Q
YES
Write title for pressure drop results
A_{16}

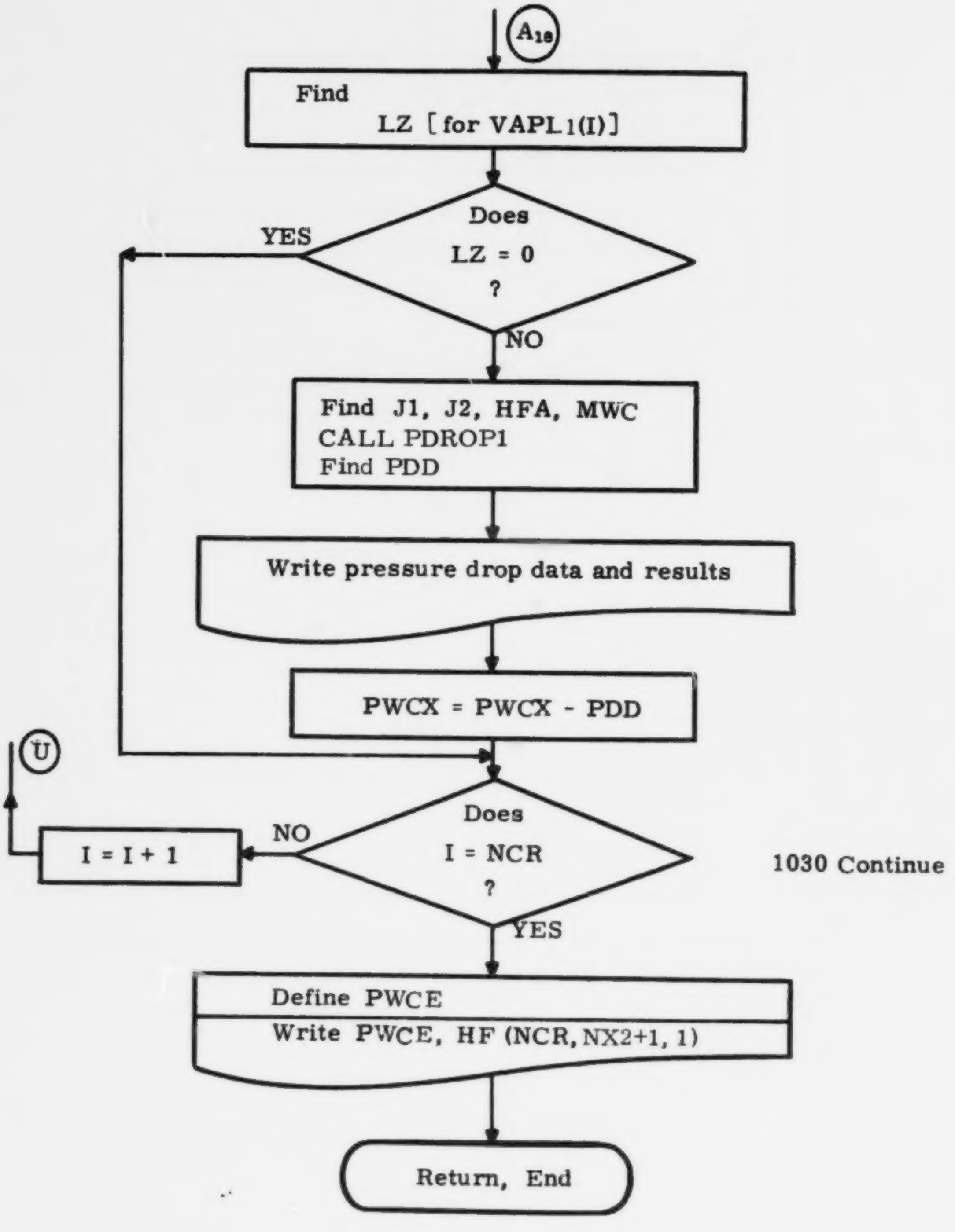
FLOW DIAGRAM -- COND (Cont'd)


A16
*Gas side pressure drop
Define PGC, TA1, TA2
CALL PDROPA
Find PDD
Repeat for all NC coils
Write for all fluid paths, pressure-drop data and results
Calculate PGCE
Write PGCE
*Fluid pressure drop
Write title for pressure drop
Define PWCX, J1
I = NCL (Fluid Pass I)
U
Do 1030
Find
J1E, LZ [for VAPL3(I)]
Does
LZ = 0
?
YES
NO
B9
A17

FLOW DIAGRAM -- COND (Cont'd)


A17
B9
Find MWC
Find J2, HFA, TX
CALL PDROP1
Find PDD
Write pressure drop data and results
PWCX = PWCX -PDD
1013
Find
LZ [for VAPL2(I)]
Does
LZ = 0
?
YES
NO
Find J1, J2, MWC
XENT (max = 1) XENT (min = 0)
CALL PDROP2
Find PDD
Write pressure drop data and results
PWCX = PWCX - PDD
1011
A18

FLOW DIAGRAM -- COND (Cont'd)


A18
Find
LZ [for VAPL1(I)]
Does
LZ = 0
?
YES
NO
Find J1, J2, HFA, MWC
CALL PDROP1
Find PDD
Write pressure drop data and results
PWCX = PWCX - PDD
U
Does
I = NCR
?
NO
I = I + 1
1030 Continue
YES
Define PWCE
Write PWCE, HF (NCR, NX2+1, 1)
Return, End

PROGRAM LISTING -- COND

```
      SUBROUTINE COND(MGI,MWE,PGCI,PGCE,PWCI,PWCE,TGCI,JS,NST)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCI,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2I(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      DIMENSION MWCZ(10,11),PGC(10)
      REAL MGI,MWCI,MWE,MWC,MWCZ,LZ,MEN1,MGCZ(10),MGCA(10)
*     SET NCYCLE=0 INITIALLY IN THE MAIN PROGRAM
      NTCOMP=2
      NC=NCY(NTCOMP)
      NCL=NCLY(NTCOMP)
      NCR=NCRY(NTCOMP)
      MWCZ(NCL,1)=MWZ(NCL,1)
      PDDT=PWCI-PWCE
      DO 3 I=NCL,NCR
      IF(NCYCLE.NE.0) GO TO 811
      CALL CGEOMC(I)
 811  CONTINUE
      MGCA(I)=MGI/(12.*L(I))
   3  CONTINUE
      PWC=PWCI
      IF(NTRANS.NE.0) GO TO 873
*     INITIALIZE
      DO 18 I=NCL,NCR
      NX2Z(I)=1
*     ASSUME AVERAGE VALUES,STATE RELATIONSHIPS NOT IMPORTANT
      HW=0.5*HFIN1(I)+0.5*HFIN2(I)
      TG=0.5*(TGIN1(I)+TGIN2(I))
*     A MORE ACCURATE TTZ CAN BE OBTAINED BY USING HEAT-TRANS. COEFFS.
      TTZ=TG
      A1=12.*L(I)
      NX2=NX2Z(I)
      CALL STEPSC(PWC,TW,HW,TG,TTZ,MWCZ(NCL,1),MGCA(I),XF,I,A1,NX2)
      IF(NX2.LE.NLUMP) GO TO 15
```

```
  10  FORMAT(41H HNO.OF LUMP REQUIRED EXCEEDS NLUMP (=10))
      WRITE(6,10)
      STOP
  15  NX2Z(I)=NX2
*     INITIAL DISTRIBUTION
      IF(I.NE.NCL) HF(I,1,1)=HFIN1(I)
      TG1(I)=TGIN1(I)
      TG2(I,1,1)=TGIN2(I)
      XN2Z=FLOAT(NX2)
      DXN=12.*L(I)/XN2Z
      A2=(HFIN2(I)-HFIN1(I))/XN2Z
      MWCZ(I,1)=MWCZ(NCL,1)
      DO 18 J=1,NX2
      MWCZ(I,J+1)=MWCZ(NCL,1)
      HF(I,J+1,1)=HF(I,J,1)+A2
*     NOTE DO NOT USE TG2,TI AT NX2+1
      TG2(I,J,1)=TGIN2(I)
      TT(I,J,1)=TW+MWCZ(I,J)*A2/(HTF*DXN)
  18  CONTINUE
      GO TO 220
 873  DO 874 I=NCL,NCR
      NX2=NX2Z(I)+1
      DO 874 J=1,NX2
 874  MWCZ(I,J)=MWZ(I,J)
*     ENTRY POINT AFTER FIRST CYCLE
 220  YREM=YEXT
      HF(NCL,1,2)=HF(NCL,1,1)
*     AT THIS POINT THE EXTERNAL CONDITIONS ARE ENTERED FOR
*     THE NEXT EXTERNAL TIME STEP.  DURING INITIALIZATION
*     THEY SHOULD BE MADE EQUAL TO THE INITIALIZING VALUES
*     PWC FROM PRESSURE COMPUTATION
*     THE FOLLOWING IS A LOOP BACK FROM STATEMENT 1000-1
 225  CONTINUE
      HF(NCL,1,2)=HF(NCL,1,1)
      CALL SATP(PWC,TSAT,GVL,GVV,HL,HV,1)
      IF(NSS.EQ.1) GO TO 733
      JS=JS+1
      IF(NST.NE.0) GO TO 6
      IF(JS.NE.LSTEP) GO TO 875
   6  WRITE(6,716)TIME,JS
 716  FORMAT(40H                                    ***** TIME = ,
     7E15.5,21H          (TIMESTEP NO.,I5,2H ))
      WRITE(6,5029)
      WRITE(6,721)HF(NCL,1,1)
 721  FORMAT(29H FLUID ENTHALPY (ENTRANCE)  =,E15.5)
      WRITE(6,722)MWCZ(NCL,1)
 722  FORMAT(29H FLUID FLOW RATE (ENTRANCE) =,E15.5)
      WRITE(6,5003)PWC,TSAT
5003  FORMAT(29H FLUID PRESSURE, SAT. TEMP  =,2E15.5)
      WRITE(6,730)MGI
 730  FORMAT(29H GAS FLOW RATE (ENTRANCE)   =,E15.5)
      WRITE(6,717)PGCI,TGCI
 717  FORMAT(29H GAS PRES, TEMP (ENTRANCE)  =,2E15.5)
 875  CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 733
      WRITE(13,704)TIME
 704  FORMAT(E15.5)
 733  CONTINUE
      DO 396 I=NCL,NCR
      NXO=NX2Z(I)
```

PROGRAM LISTING -- COND (Cont'd)

```
      NX2MAX(I)=1
      VAPL1(I)=0.
      VAPL2(I)=0.
      VAPL3(I)=0.
      J2E(I)=0
      J3E(I)=0
      DX0=12.*L(I)/FLOAT(NX0)
      MGCA(I)=MGI/(12.*L(I))
      DO 230 JI=1,NX0
      HW=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      TA=(TG1(I)+TG2(I,JI,1))/2.
      TTZ=TT(I,JI,1)
      A1=L(I)*12.
      MWC=MWCZ(I,JI)
      NX2=NX2Z(I)
      CALL STEPSC(PWC,TW,HW,TA,TTZ,MWC,MGCA(I),XF,I,A1,NX2)
*     THE FOLLOWING ARE AVAILABLE FROM STEPSI AND ARE BULK
      RWY(I,JI)=RW
      HGTY(I,JI)=HGT
      HTFY(I,JI)=HTF
      EFY(I,JI)=EF
      CTFY(I,JI)=CTF
      NPHY(I,JI)=NPH
      NX2MAX(I)=MAX0(NX2MAX(I),NX2)
 230  CONTINUE
      NXN=NX2MAX(I)
      NX2Z(I)=NXN
      DXN=12.*L(I)/FLOAT(NXN)
      DX2=DXN
      IF(NSS.EQ.1) GO TO 707
      IF(I.EQ.NCL) DXN1=DX2
      IF(I.EQ.(NCL+1)) DXN2=DX2
      IF(NSI.NE.0) GO TO 200
      IF(JS.NE.LSTEP) GO TO 714
 200  IF(I.LT.NCR) GO TO 714
      WRITE(6,713)DXN1,DXN2,DX2
 713  FORMAT(29H LUMP SIZE (COILS 1,2,3)     =,3E15.5)
      WRITE(6,5029)
 714  CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 707
      WRITE(13,706)NXN
 706  FORMAT(I10)
 707  CONTINUE
      IF(NXN.EQ.NX0) GO TO 237
      MA=NX0+1
      DO 806 JI=1,MA
 806  MWZ(I,JI)=MWCZ(I,JI)
      CALL DISTR(I)
      MA=NXN+1
      DO 807 JI=1,MA
 807  MWCZ(I,JI)=MWZ(I,JI)
      DO 236 JI=1,NXN
      HW=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      IF(HW-HL) 231,232,232
 231  NPH=1
      GO TO 235
 232  IF(HW-HV) 233,233,234
 233  NPH=2
      GO TO 235
 234  NPH=3
```

PROGRAM LISTING -- COND (Cont'd)

```
 235  NPHY(I,JI)=NPH
 236  CONTINUE
 237  DO 238 JI=1,NXN
      IF(NSS.EQ.1) GO TO 238
      NPH=NPHY(I,JI)
*     LOCATE INTERPHASES
      IF(NPH-2)229,226,227
 226  VAPL2(I)=VAPL2(I)+(DX2*ACI(I))
      J2E(I)=J2E(I)+1
      GO TO 229
 227  VAPL3(I)=VAPL3(I)+(DX2*ACI(I))
      J3E(I)=J3E(I)+1
 229  VAPL1(I)=12.*ACI(I)*L(I)-VAPL2(I)-VAPL3(I)
      IF(VAPL1(I).LT.DX2*ACI(I)/2.) VAPL1(I)=0.
 238  CONTINUE
      DYYM=YREM
      DO 265 JI=1,NXN
      X2=2.*(EFY(I,JI)/HTFY(I,JI))
      DYX1=CTT(I)/(HGTY(I,JI)+HTFY(I,JI))
      DYX2=(2.*CTFY(I,JI)/HTFY(I,JI))/((X2/DXN)+1.)
      DYX3=ABS(RWY(I,JI)*ACI(I)*DXN/(MWCZ(I,JI)*1728.))
      IF(NPHY(I,JI).EQ.1) DYY=FRAC*AMIN1(DYX1,DYX2)
      IF(NPHY(I,JI).EQ.2) DYY=FRAC*AMIN1(DYX1,DYX3)
      IF(NPHY(I,JI).EQ.3) DYY=FRAC*DYX1
      DYYM=AMIN1(DYYM,DYY)
 265  CONTINUE
      DXN=DX2
      DYYY(I)=DYYM
 396  CONTINUE
      DYY=YREM
      DO 412 I=NCL,NCR
 412  DYY=AMIN1(DYY,DYYY(I))
      IF(NSS.EQ.0) GO TO 734
      CALL ITERAT(PGCI,MGI,TSAT,MWCZ(NCL,1),HL,HV,PWCI,JS,NC,
     7NCL,2)
      IF(NSS.EQ.1) GO TO 733
      IF(NST.NE.1) GO TO 734
      WRITE(6,716)TIME,JS
 734  CONTINUE
      INX1=1
      INX2=1
      QTOT=0.
      DO 600 I=NCL,NCR
      NXN=NX2Z(I)
      DXN=12.*L(I)/FLOAT(NXN)
      TG2T=0.
      IF(NST.NE.0) GO TO 53
      IF(JS.NE.LSTEP) GO TO 64
  53  IF(I.NE.NCL) GO TO 703
      WRITE(6,702)
 702  FORMAT(3X,5H LUMP,10X,3H H2,14X,3H TF,14X,3H IT,13X,4H TG2,
     714X,3H M2,10X,4H NPH)
 703  CONTINUE
      WRITE(6,20) I
  20  FORMAT(38X,5H*****,16H FLUID PASS NO. ,I5,5H*****)
  64  CONTINUE
      DO 420 JI=1,NXN
      NPH=NPHY(I,JI)
      TG=(TG1(I)+TG2(I,JI,1))/2.
      CGG=FCA(TG)
      X1=2.*MGI*CGG/(HGTY(I,JI)*L(I)*12.)
      BB=1./X1
      TGN=TG1(I)
      NBB=1
      IF(BB.GT.0.5) NBB=2.5*BB
      BB=BB/FLOAT(NBB)
      FG2G1=(1.-BB)/(1.+BB)
      FG2T=1.-FG2G1
      ADT=FG2T*TT(I,JI,1)
      DO 280 LI=1,NBB
  280 TGN=FG2G1*TGN+ADT
      TG2(I,JI,2)=TGN
      TG2(I,JI,1)=TG2(I,JI,2)
      TG2T=TG2T+TG2(I,JI,2)
      GO TO (397,398,399),NPH
  397 TREF=TSAT
      HFAVG=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      HREF=HL
      CPP=FCWL(TREF)
      TX=TREF
  740 TX1=TREF+(HFAVG-HREF)/CPP
      IF(ABS((TX-TX1)/TX)-.01) 742,742,741
  741 TX=(TX1+TX)/2.
      CPP=FCWL(TX)
      GO TO 740
  742 FTG=(DYY/2.)*(HGTY(I,JI)/CTT(I))
      FTT=1.-(DYY/CTT(I))*(HTFY(I,JI)+HGTY(I,JI))
      FTF=(DYY/2.)*HTFY(I,JI)/(CTT(I)*CPP)
      FCON=DYY*(HTFY(I,JI)/CTT(I))*(TREF-(HREF/CPP))
      TT(I,JI,2)=FTT*TT(I,JI,1)+FTF*(HF(I,JI,1)+HF(I,JI+1,1))+
     4FTG*(TG1(I)+TG2(I,JI,1))+FCON
      MWCZ(I,JI+1)=MWCZ(I,JI)
      FF2T=DYY*(HTFY(I,JI)/CTFY(I,JI))*CPP
      FF2F1=(DYY/DXN)*(EFY(I,JI)/CTFY(I,JI))*(1.-(HTFY(I,JI)/
     4EFY(I,JI))*(DXN/2.))
      FF2F2=1.-(DYY/CTFY(I,JI))*((HTFY(I,JI)/2.)+(EFY(I,JI)/DXN))
      HF(I,JI+1,2)=FF2F2*HF(I,JI+1,1)+FF2F1*HF(I,JI,1)+
     5FF2T*(TT(I,JI,1)-TREF+(HREF/CPP))
      HFN=HF(I,JI+1,1)
      TFX=TX1
      GO TO 410
  398 IF(INX1.NE.1) GO TO 2000
      HEN1=HF(I,JI,1)
      HENN1=HF(I,JI,2)
      MEN1=MWCZ(I,JI)
      INX1=2
 2000 CONTINUE
      DRODH=((1./GVL)-(1./GVV))/(HL-HV)
      FTG=(DYY/2.)*HGTY(I,JI)/CTT(I)
      FTT=1.-(DYY/CTT(I))*(HTFY(I,JI)+HGTY(I,JI))
      FTF=DYY*HTFY(I,JI)/CTT(I)
      TT(I,JI,2)=FTT*TT(I,JI,1)+FTF*TSAT+FTG*(TG1(I)+TG2(I,JI,1))
      HAVG1=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      XE1=(HAVG1-HL)/(HV-HL)
      IF(XE1.LT.0.) XE1=0.
      IF(XE1.GT.1.) XE1=1.
      RO=(1./GVL)+XE1*((1./GVV)-(1./GVL))
      VBAR=1728./(RO*ACI(I))
      FF2F1=(DYY/DXN)*VBAR*MWCZ(I,JI)
      FF2F2=1.-FF2F1
```

PROGRAM LISTING -- COND (Cont'd)

```
      FF2T=DYY*VBAR*HTFY(I,JI)
      HF(I,JI+1,2)=FF2F2*HF(I,JI+1,1)+FF2F1*HF(I,JI,1)+FF2T*
     6(TT(I,JI,1)-TSAT)
      TFX=TSAT
      HFN=HF(I,JI+1,1)
      DELTH=HF(I,JI,1)-HF(I,JI+1,1)
      TERM1=(TT(I,JI,1)-TSAT)*HTFY(I,JI)*DXN
      PREF=-DRODH/RO
      WCZ=MWCZ(I,JI)
      TERM2=PREF*DELTH
      TERM3=PREF*TERM1
      WCZ=WCZ*(1.+TERM2)+TERM3
      MWCZ(I,JI+1)=WCZ
      HEX1=HF(I,JI+1,1)
      HEXN1=HF(I,JI+1,2)
      GO TO 410
  399 IF(INX2.NE.1) GO TO 813
      HFA=HF(I,JI,1)
      HFB=HF(I,JI+1,1)
      GO TO 814
  813 HFA=HF(I,JI,2)
      HFB=HF(I,JI+1,2)
  814 HFAVG=(HFA+HFB)/2.
      CALL SUPPT(PWC,TFX,HFAVG,DD,GV,3)
      GVZ(I,JI,1)=GV
      HREF=HFAVG+5.
      CALL SUPPT(PWC,TREF,HREF,DD,DD,3)
      CPP=(HFAVG-HREF)/(TFX-TREF)
      X1=ABS(2.*MWCZ(I,JI)*CPP/HTFY(I,JI))
      BB=DXN/X1
      FF2F1=(1.-BB)/(1.+BB)
      FF2T=2.*BB/(1.+BB)
      HF(I,JI+1,2)=FF2F1*HFA+FF2T*(CPP*(TT(I,JI,1)-TREF)
     7+HREF)
      HEX2=HF(I,JI+1,1)
      FTG=(DYY/2.)*(HGTY(I,JI)/CTT(I))
      FTT=1.-(DYY/CTT(I))*(HTFY(I,JI)+HGTY(I,JI))
      FTF=(DYY/2.)*HTFY(I,JI)/(CTT(I)*CPP)
      FCON=DYY*(HTFY(I,JI)/CTT(I))*(TREF-(HREF/CPP))
      TT(I,JI,2)=FTT*TT(I,JI,1)+FTF*(HFA+HF(I,JI+1,2))+
     4FTG*(TG1(I)+TG2(I,JI,1))+FCON
      HEXN2=HF(I,JI+1,2)
      HFAVG=(HF(I,JI,2)+HF(I,JI+1,2))/2.
      CALL SUPPT(PWC,TWC,HFAVG,DD,GV,3)
      GVZ(I,JI,2)=GV
      HFN=HEX2
  406 MWCZ(I,JI+1)=MWCZ(I,JI)+(DXN/DYY)*ACT(I)*(GVZ(I,JI,2)-
     7GVZ(I,JI,1))/(GVZ(I,JI,1)*GVZ(I,JI,2)*1728.)
  410 CONTINUE
      QTOT=QTOT+HTFY(I,JI)*DXN*(TT(I,JI,1)-TFX)
 5029 FORMAT(2H  )
      IF(NST.NE.0) GO TO 72
      IF(JS.NE.LSTEP) GO TO 876
   72 WRITE(6,5032)JI,HFN,TFX,TT(I,JI,1),TG2(I,JI,1),
     7MWCZ(I,JI+1),NPHY(I,JI)
 5032 FORMAT(I6,4X,5E17.5,I6)
  876 CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 709
      WRITE(13,708)HFN,TT(I,JI,1),TG2(I,JI,1),MWCZ(I,JI+1)
  708 FORMAT(4E15.5)
```

PROGRAM LISTING -- COND (Cont'd)

```
 709  CONTINUE
      IF(NPRINT.NE.0) GO TO 5021
      WRITE(6,5033)HTFY(I,JI),CTFY(I,JI),EFY(I,JI),HGTY(I,JI)
5033  FORMAT(17H HTF,CTF,EF,HGT  ,4F15.5)
5021  CONTINUE
      IF(JI.NE.NXN) GO TO 420
      IF(I.EQ.NCR) GO TO 420
      MWCZ(I+1,1)=MWCZ(I,NXN+1)
      HF(I+1,1,2)=HF(I,NXN+1,2)
 420  CONTINUE
      TG2AVG(I)=TG2T/FLOAT(NXN)
      IF(I-NCL-1) 421,423,600
 421  TG1(NCL+1)=TG2AVG(NCL)
      GO TO 600
 423  TG1(NCR)=TG2AVG(NCL+1)
 600  CONTINUE
      TIME=TIME+DYY
*     PRESSURE CALCULATION
      VAL1=0.
      VAL2=0.
      VAL3=0.
      UM=0.
      DENM=0.
      DO 610 J=NCL,NCR
      VAL1=VAL1+VAPL1(J)
      VAL2=VAL2+VAPL2(J)
 610  VAL3=VAL3+VAPL3(J)
      IF((VAL2+VAL3).EQ.0.) GO TO 635
      VAL=VAL1+VAL2+VAL3
      HFG=HV-HL
      GFG=GVV-GVL
      AX=GFG/HFG
      DELH=2.
      DELP=2.
      PLOW=PWC-DELP
      IF(VAL2.EQ.0.) GO TO 620
      HFAV1=(HEN1+HEX1)/2.
      XAV1=(HFAV1-HL)/(HV-HL)
      IF(XAV1.LT.0.0) XAV1=0.
      IF(XAV1.GT.1.) XAV1=1.
      WG=XAV1*VAL2/(1728.*GVV)
      WF=(1.-XAV1)*VAL2/(1728.*GVL)
      CALL SATP(PLOW,DD,GVL1,GVV1,HL1,HV1,1)
      AR1=WG*(HV-HV1)/DELP
      AR2=WF*(HL-HL1)/DELP
      AR3=WF*(GVL-GVL1)/DELP
      AR4=WG*(GVV-GVV1)/DELP
      DENM=DENM+AX*(AR1+AR2)-(AR3+AR4)
      IF(NPRINT.NE.0) GO TO 620
      WRITE(6,823)HEN1,HEX1,HFAV1
      WRITE(6,823)HL,HV,XAV1,VAL2,GVV,GVL
      WRITE(6,823)WG,WF,PLOW,GVL1,GVV1
      WRITE(6,823)HL1,HV1,DELP,AR1,AR2
      WRITE(6,823)AR3,AR4,DENM,AX
 823  FORMAT(7H VAP1  ,6E15.5)
 620  IF(VAL3.EQ.0.) GO TO 630
      HFAV1=(HF(NCL,1,1)+HEN1)/2.
      HFAV2=(HF(NCL,1,1)+HENN1)/2.
      CALL SUPPT(PWC,TAV1,HFAV1,DD,GAV1,3)
      CALL SUPPT(PLOW,DD,HFAV1,DD,GAV2,3)
```

PROGRAM LISTING -- COND (Cont'd)

```
      CALL SUPPT(PWC,DD,HFAV1-DELH,DD,GAV3,3)
      WS=VAL3/(1728.*GAV1)
      AX1=(GAV3-GAV1)/DELH
      AX2=WS*(GAV1-GAV2)/DELP
      UM=UM+WS*(AX1-AX)*(HFAV2-HFAV1)/DYY
      DENM=DENM-AX2
      IF(NPRINT.NE.0) GO TO 630
      WRITE(6,824)UM,DENM
  824 FORMAT(7H VAP2  ,2E15.5)
  630 NX2=NX2Z(NCR)
      AS1=AX*(QTOT-MWCZ(NCL,1)*(HL-HF(NCL,1,1))-MWE*
     7(HF(NCR,NX2+1,1)-HL))
      AS2=(MWCZ(NCL,1)-MWE)*GVL
      UM=UM+AS1+AS2
      DENM=DENM-AX*VAL/(12.*778.)
      PINCT=UM*DYY/DENM
      IF(NPRINT.NE.0) GO TO 640
      WRITE(6,825)HFAV1,HFAV2,HEN1,HENN1
      WRITE(6,825)TAV1,GAV1,GAV2,GAV3
      WRITE(6,825)VAL3,WS,AX1,AX2
      WRITE(6,825)UM,AX,DENM,AS1,QTOT
      WRITE(6,825)MWCZ(NCL,1),HL,HF(NCL,1,1),MWE
      WRITE(6,825)HF(NCR,NX2+1,1),AS2,GVL
  825 FORMAT(7H VAP3  ,5E15.5)
      WRITE(6,5062)PINCT
 5062 FORMAT(8H PINCT  ,E15.5)
      GO TO 640
  635 PINCT=0.
  640 PWCE=PWCE+PINCT
      PWC=PWCE+PDOT
      WRITE(6,5029)
*     RESET
      KK1=NCR-1
      DO 429 JL=NCL,KK1
  429 TG1(JL+1)=TG2AVG(JL)
      DO 430 I=NCL,NCR
      NXN=NX2Z(I)
      IF(I.EQ.NCL) GO TO 645
      HF(I,1,1)=HF(I,1,2)
  645 CONTINUE
      MWZ(I,NXN+1)=MWCZ(I,NXN+1)
      DO 430 JJ=1,NXN
      TT(I,JJ,1)=TT(I,JJ,2)
      HF(I,JJ+1,1)=HF(I,JJ+1,2)
      MWZ(I,JJ)=MWCZ(I,JJ)
  430 CONTINUE
      YREM=YREM-DYY
      IF(NST.NE.0) GO TO 77
      IF(JS.NE.LSTEP) GO TO 877
   77 WRITE(6,701)DYY,TG1(NCL),TG1(NCL+1),TG1(NCR)
  701 FORMAT(10H DYY,TG1  ,4E15.5)
  877 CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 712
      WRITE(13,711) TG1(NCL),TG1(NCL+1),TG1(NCR)
  711 FORMAT(3E15.5)
  712 CONTINUE
      IF(JS.NE.LSTEP) GO TO 225
 1000 CONTINUE
*     GAS-SIDE PRESSURE DROP
      WRITE(6,5029)
```

PROGRAM LISTING -- COND (Cont'd)

```
      CALL SUPPT(PWC,DD,HFAV1,DELH,DD,GAV3,3)
      WS=VAL3/(1728.*GAV1)
      AX1=(GAV3-GAV1)/DELH
      AX2=WS*(GAV1-GAV2)/DELP
      UM=UM+WS*(AX1-AX)*(HFAV2-HFAV1)/DYY
      DENM=DENM-AX2
      IF(NPRINT.NE.0) GO TO 630
      WRITE(6,824)UM,DENM
  824 FORMAT(7H VAP2  ,2E15.5)
  630 NX2=NX2Z(NCR)
      AS1=AX*(QTOT-MWCZ(NCL,1)*(HL-HF(NCL,1,1))-MWE*
     7(HF(NCR,NX2+1,1)-HL))
      AS2=(MWCZ(NCL,1)-MWE)*GVL
      UM=UM+AS1+AS2
      DENM=DENM-AX*VAL/(12.*778.)
      PINCT=UM*DYY/DENM
      IF(NPRINT.NE.0) GO TO 640
      WRITE(6,825)HFAV1,HFAV2,HEN1,HENN1
      WRITE(6,825)TAV1,GAV1,GAV2,GAV3
      WRITE(6,825)VAL3,WS,AX1,AX2
      WRITE(6,825)UM,AX,DENM,AS1,QTOT
      WRITE(6,825)MWCZ(NCL,1),HL,HF(NCL,1,1),MWE
      WRITE(6,825)HF(NCR,NX2+1,1),AS2,GVL
  825 FORMAT(7H VAP3  ,5E15.5)
      WRITE(6,5062)PINCT
 5062 FORMAT(8H PINCT  ,E15.5)
      GO TO 640
  635 PINCT=0.
  640 PWCE=PWCE+PINCT
      PWC=PWCE+PDUT
      WRITE(6,5029)
*     RESET
      KK1=NCR-1
      DO 429 JL=NCL,KK1
  429 TG1(JL+1)=TG2AVG(JL)
      DO 430 I=NCL,NCR
      NXN=NX2Z(I)
      IF(I.EQ.NCL) GO TO 645
      HF(I,1,1)=HF(I,1,2)
  645 CONTINUE
      MWZ(I,NXN+1)=MWCZ(I,NXN+1)
      DO 430 JJ=1,NXN
      TT(I,JJ,1)=TT(I,JJ,2)
      HF(I,JJ+1,1)=HF(I,JJ+1,2)
      MWZ(I,JJ)=MWCZ(I,JJ)
  430 CONTINUE
      YREM=YREM-DYY
      IF(NST.NE.0) GO TO 77
      IF(JS.NE.LSTEP) GO TO 877
   77 WRITE(6,701)DYY,TG1(NCL),TG1(NCL+1),TG1(NCR)
  701 FORMAT(10H DYY,TG1  ,4E15.5)
  877 CONTINUE
      IF(JS.NE.LSTEP-1) GO TO 712
      WRITE(13,711) TG1(NCL),TG1(NCL+1),TG1(NCR)
  711 FORMAT(3E15.5)
  712 CONTINUE
      IF(JS.NE.LSTEP) GO TO 225
 1000 CONTINUE
*     GAS-SIDE PRESSURE DROP
      WRITE(6,5029)
      WRITE(6,5029)
      WRITE(6,851)
  851 FORMAT(46X,28H ** PRESSURE DROP RESULTS **)
      WRITE(6,852)
  852 FORMAT(12H ** GAS SIDE)
      WRITE(6,853)
  853 FORMAT(3X,5H PASS,7X,10H MASS FLOW,9X,8H INLET P,10X,
     78H INLET T,10X,7H EXIT T,10X,9H PR. DROP)
      DO 1008 I=NCL,NCR
      MGCZ(I)=MGI/TUBROW(I)
      DIST=12.*L(I)
      TA1=TG1(I)
      TA2=TG2AVG(I)
      IF(I.NE.NCL) GO TO 1002
      PGC(I)=PGCI
      GO TO 1003
 1002 PGC(I)=PGC(I-1)-PDD
 1003 CALL PDROPA(PGC(I),TA1,TA2,MGCZ(I),NSO(I),DHO(I),DO(I),ACO(I),
     7DIST,X2L(I),FNO(I),FHO(I),FTO(I),RM(I),PDD)
      WRITE(6,754)I,MGCZ(I),PGC(I),TG1(I),TG2AVG(I),PDD
  754 FORMAT(I6,4X,5E17.5)
 1008 CONTINUE
      PGCE=PGC(NCR)-PDD
      WRITE(6,871)PGCE,TG2AVG(NCR)
  871 FORMAT(25H EXIT PRESSURE, TEMP      ,2E15.5)
*     FLUID PRESSURE DROP
      WRITE(6,856)
  856 FORMAT(14H ** FLUID SIDE)
      WRITE(6,857)
  857 FORMAT(3X,5H PASS,9X,5H FLOW,14X,4H NPH,12X,7H LENGTH,
     79X,11H INLET PRES,8X,9H PR. DROP)
      PWCX=PWCI
      J1=1
      DO 1030 I=NCL,NCR
      LZ=VAPL3(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1013
      J2=J3E(I)+J1
      HFA=(HF(I,J1,1)+HF(I,J2,1))/2.
      MWC=(MWCZ(I,J1)+MWCZ(I,J2))/2.
      CALL SUPPT(PWCX,TWC,HFA,DD,DD,3)
      CALL PDROP1(PWCX,TWC,MWC,DHI(I),ACI(I),LZ,3,PDD,DD,DD,DD)
      NPH=3
      WRITE(6,858)I,MWC,NPH,LZ,PWCX,PDD
  858 FORMAT(I6,4X,E17.5,I9,8X,3E17.5)
      PWCX=PWCX-PDD
 1013 LZ=VAPL2(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1011
      J1=J3E(I)+1
      J2=J2E(I)+J1
      MWC=(MWCZ(I,J1)+MWCZ(I,J2))/2.
      CALL SATP(PWCX,TWC,DD,DD,HL,HV,1)
      XENT=(HF(I,J1,1)-HL)/(HV-HL)
      XEXT=(HF(I,J2,1)-HL)/(HV-HL)
      IF(XENT.GT.1.) XENT=1.
      IF(XEXT.LT.0.) XEXT=0.
      CALL PDROP2(PWCX,TWC,XENT,XEXT,MWC,DHI(I),ACI(I),LZ,PDD)
      NPH=2
      WRITE(6,858)I,MWC,NPH,LZ,PWCX,PDD
      PWCX=PWCX-PDD
 1011 LZ=VAPL1(I)/(12.*ACI(I))
```

PROGRAM LISTING -- COND (Cont'd)

```
      IF(LZ.EQ.0.) GO TO 1030
      J1=J3E(I)+J2E(I)+1
      J2=NX2Z(I)+1
      MWC=(MWCZ(I,J1)+MWCZ(I,J2))/2.
 1012 CALL SATP(PWCX,TWC,DD,DD,DD,DD,1)
      CALL PDROP1(PWCX,TWC,MWC,DHI(I),ACI(I),LZ,1,PDD,DD,DD,DD)
      NPH=1
      WRITE(6,858)I,MWC,NPH,LZ,PWCX,PDD
      PWCX=PWCX-PDD
 1030 CONTINUE
      PWCE=PWCX
      NX2=NX2Z(NCR)
      WRITE(6,859)PWCE,HF(NCR,NX2+1,1)
  859 FORMAT( 5H EXIT PRESSURE, ENTH      ,2E15.5)
      RETURN
      END
```

SUBROUTINE CGEOMC

CGEOMC calculates all geometric constants for COND.

NOMENCLATURE -- CGEOMC

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of CGEOMC are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
NC	Fluid pass number	--

PROGRAM LISTING -- CGEOMC

```
      SUBROUTINE CGEOMC(NC)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2F(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIMF,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
*     HYDRAULIC DIAMETERS
*     USE FUNCTIONS
      VOLB=DO(NC)*BH(NC)-DI(NC)*BT(NC)
      ACO(NC)=X2L(NC)-DO(NC)-FNO(NC)*FHO(NC)*FTO(NC)
      DHO(NC)=2.*(X2L(NC)-DO(NC))/(1.+FNO(NC)*FHO(NC))
      VOLO=FHO(NC)*FTO(NC)*BH(NC)*FNO(NC)
      ACI(NC)=DI(NC)*BT(NC)
      DHI(NC)=2.*DI(NC)*BT(NC)/(DI(NC)+BT(NC))
*     TUBE METAL PROPERTIES ARE ASSUMED CONSTANT IN THIS PROGRAM
*     ARRANGEMENT
      TX=0.
      MI=NM(NC)
      GO TO (140,145),MI
*     NOTE THAT AT PRESENTLY FORMULATED THE FUNCTIONS FCMS(TX),
*     FRMS(TX),FCMC(TX),FRMC(TX).  THEY DO NOT DEPEND ON TEMPERATURE
*     WHICH IS NOT DEFINED AT THIS POINT. (SUITABLE TEMPERATURES
*     COULD BE DEFINED FOR THIS PURPOSE)
 140  CTB=FCMS(TX)
      RTB=FRMS(TX)
      GO TO 150
 145  CTB=FCMC(TX)
      RTB=FRMC(TX)
 150  MI=NMO(NC)
      GO TO (155,160),MI
 155  CTO=FCMS(TX)
      RTO=FRMS(TX)
      GO TO 180
 160  CTO=FCMC(TX)
```

PROGRAM LISTING -- CGEOMC (Cont'd)

```
      RTO=FRMC(IX)
180   CTT(NC)=VOLB*CTB*RTB
      IF(NSO(NC).NE.1) CTT(NC)=CTT(NC)+VOLO*CTO*RTO
      CTT(NC)=CTT(NC)/1728.
      RETURN
      END
```

SUBROUTINE STEPSC

STEPSC calculates the stability limit on lump-size for each lump of COND. It employs the subroutines HT1PB, HT2PB, HTAC, and PHASE.

NOMENCLATURE -- STEPSC

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of STEPSC are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
HW	Enthalpy of working fluid	Btu/lb
MGC	Mass flow rate of air	lb/sec
MWC	Mass flow rate of working fluid	lb/sec
NC	Fluid pass number	--
NX2	Number of lumps for a given coil	--
PW	Pressure of working fluid	$lb/in.^2$
TG	Bulk gas temperature	°F
TI	Wall temperature at mid-node of a lump	°F
TW	Bulk fluid temperature	°F
X	Quality of bulk mass within a lump	--
X2G	Geometric limit on lump size	in.

PROGRAM LISTING -- STEPSC

```
      SUBROUTINF STEPSC(PW,TW,HW,TG,TI,MWC,MGC,X,NC,X2G,NX2)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEX1
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MWC,MGC
*     PW,HW,TG,TI,MWC,MGC,NC,X2G ARE INPUT
*     NX2,X,TW ARE RETURNED.
      CALL PHASF(PW,TW,HW,X,GVL,GVV,HL,HV)
*     GAS PROPERTIES
      CG=FCA(TG)
      RG=1./FDA(TG)
*     OHTAIN HEAT TRANS COEFFS; HTGT,HTTF
*     OBTAINING HTGT
      G=MGC/ACO(NC)
      CALL HTAC(HTGT,NC,G,TG)
*     OBTAINING HTTF
      GF=ABS(MWC/ACI(NC))
      MI=NSI(NC)
      GO TO (60,70,60),NPH
   60 CALL HT1PB(HTTF,NC,GF,PW,TW)
      GO TO 100
   70 CALL HT2PC(HTTF,NC,GF,TW,TI,1./GVV,1./GVL,X,HV-HL)
  100 CONTINUE
*     COMPUTE THT PARAMETERS
      EG=ABS(MGC*12.*L(NC)*CG)/FLOAT(NX2)
      EF=ABS(MWC*CW)
      HGT=HTGT*2.*(DO(NC)+BH(NC))
      HTF=HTTF*2.*(DI(NC)+BT(NC))
      CTF=RW*ACI(NC)*CW/1728.
*     STEP SIZE CALCULATION
      X2=2.*EF/HTF
      DX2=AMIN1(X2*FRAC,X2G)
```

PROGRAM LISTING -- STEPSC (Cont'd)

```
NX2=INTSTE(DX2,X2G)
IF(NPH.EQ.2) NX2=5
IF(NX2.GT.1) DX2=X2G/FLOAT(NX2)
RETURN
END
```

SUBROUTINE HT2PC

HT2PC calculates the heat transfer coefficient between the condensing fluid and the condenser wall.

NOMENCLATURE -- HT2PC

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HT2PC are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
G	Mass velocity of working fluid	lb/in.^{2} sec
HFG	Latent heat enthalpy	Btu/lb
HTC	Heat transfer coefficient	Btu/sec in.^{2} °F
NC	Fluid pass number	--
RHOL	Density of working fluid liquid phase	lb/ft^3
RHOV	Density of working fluid vapor phase	lb/ft^3
TI	Wall temperature at mid-node of a lump	°F
TTF	Bulk fluid temperature	°F
X	Bulk quality of working fluid	--

PROGRAM LISTING -- HT2PC

```
      SUBROUTINE HT2PC(HTC,NC,G,TTF,TI,RHOV,RHOL,X,HFG)
*     THIS SUBROUTINE CALCULATES THE HEAT TRANSFER COEFFICIENT
*     BETWEEN THE CONDENSING FLUID AND THE CONDENSER WALL
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,S1A
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL KL
      VISL=FVWL(TTF)
      KL=FKWL(TTF)
      CL=FCWL(TTF)
      GL=(1.-X)*G
      GV=X*G
      REL=(DHI(NC)*GL/VISL)*3600.*12.
      REV=(DHI(NC)*GV/VISL)*SQRT(RHOL/RHOV)*3600.*12.
      IF(REL.GT.5000.) GO TO 20
      IF(REV.GT.20000.) GO TO 10
      TERM=13.8/(3600.*12.)
      ZEXP=.2
      GO TO 15
 10   TERM=.1/(3600.*12.)
      ZEXP=2./3.
 15   HTC=(TERM*KL/DHI(NC))*(CL*VISL/KL)**(1./3.)
     1  *(HFG/(CL*ABS(TTF-TI)))**(1./6.)*REV**ZEXP
      GO TO 30
 20   GE=GV*(RHOL/RHOV)**.5+GL
      TERM=.026*(3600.*12.)**.8/(3600.*12.)
      HTC=(TERM*KL/DHI(NC))*(CL*VISL/KL)**(1./3.)
     1  *(DHI(NC)*GE/VISL)**.8
 30   CONTINUE
      RETURN
      END
```

SUBROUTINE HTAC

HTAC calculates the heat transfer coefficient between the air and condenser tube wall for the louvered fin condenser.

NOMENCLATURE -- HTAC

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HTAC are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
G	Mass velocity of air	lb/in.^{2} sec
HTC	Heat transfer coefficient	Btu/sec in.^{2} °F
NC	Fluid pass number	--
TTF	Bulk air temperature	°F

PROGRAM LISTING -- HTAC

```
      SUBROUTINE HTAC(HTC,NC,G,TTF)
*     THIS SUBPOUTINE CALCULATES THE HEAT TRANSFER COEFFIENT
*     BETWEEN THE AIR AND CONDENSER TUBE WALL FOR THE
*     LOUVERED FIN CONDENSER
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDB,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL K,KM
      IF(NMO(NC).EQ.1) KM=25.
      IF(NMO(NC).EQ.2) KM=223.
      V=FVA(TTF)
      K=FKA(TTF)
      C=FCA(TTF)
      REA=(DHO(NC)*G/V)*3600.*12.
      Z=REA*1.E-3
      Y=ALOG(Z)
      BETA=-.0184*Y**3+.11*Y**2-.688*Y+.6678
      YA=.01*EXP(BETA)
      HTB=YA*G*C*(C*V/K)**(-2./3.)
      B=SQRT(12.*3600.*2.*HTB/(KM*FTO(NC)))
      ETA=TANH(B*FHO(NC))/(B*FHO(NC))
      AF=2.*FNO(NC)*((BH(NC)+DO(NC))*(2.*FHO(NC)+FTO(NC))+
     7 4.*FHO(NC)*(FHO(NC)+FTO(NC)))
      AU=2.*(BH(NC)+DO(NC))*(1.-FNO(NC)*FTO(NC))
      A=AF+AU
      AFAT=AF/A
      EFF=1.-AFAT*(1.-ETA)
      HTC=HTB*EFF*A/(2.*(BH(NC)+DO(NC)))
      RETURN
      END
```

Section 8

REGENERATOR MODEL

MAIN PROGRAM – REGEN

The regenerator model is titled REGEN. The model employs the following subroutines:

DISTR
RGEOMC
STEPSR
ITERAT
SATP
PROP
SUPPT
PROPST
PDROP1
PDROP2
PDROPR
INTSTE
PHASE
HT1PB
HT2PB
HTWTM
FCWL
FDWL
FKWL
FVWL
FYWL
FCWV
FDWV
FKWV
FVWV
FCA
FDA
FKA
FVA
FCG
FDG
FKG
FVG
FCMC
FKC
FRMC
FCMS
FKS
FRMS
FKM

Figure 3 illustrates the links between the various subroutines required for REGEN.

The input parameter, FRAC, is the ratio of actual step size to stability step size. To avoid numerical instability, its value should be less than unity. FRAC has been set at 0.5 in the present program.

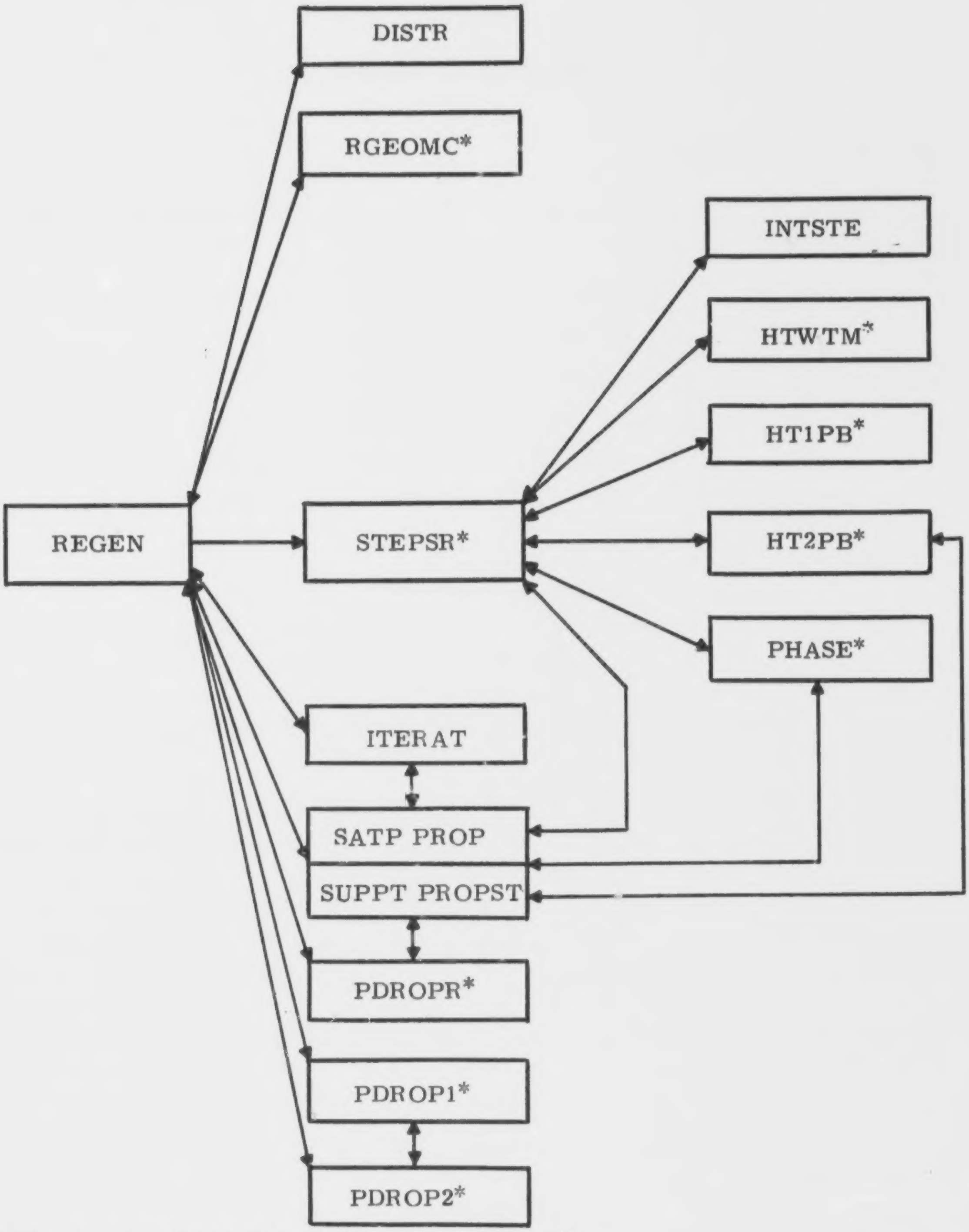
NOMENCLATURE -- REGEN

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of REGEN are in the COMMON of MAINSYS.

Fortran Variables in Argument List:

FORTRAN Variable	Definition	Units
HGRI	Enthalpy of vapor at REGEN inlet	Btu/lb
JS	Variable to denote cumulative number of time steps	--


DISTR
RGEOMC*
INTSTE
HTWTM*
HT1PB*
REGEN
STEPSR*
HT2PB*
PHASE*
ITERAT
SATP PROP
SUPPT PROPST
PDROPR*
PDROP1*
PDROP2*

*These subroutines use fluid or metal properties.

Figure 3. Links Between Subroutines Used by REGEN

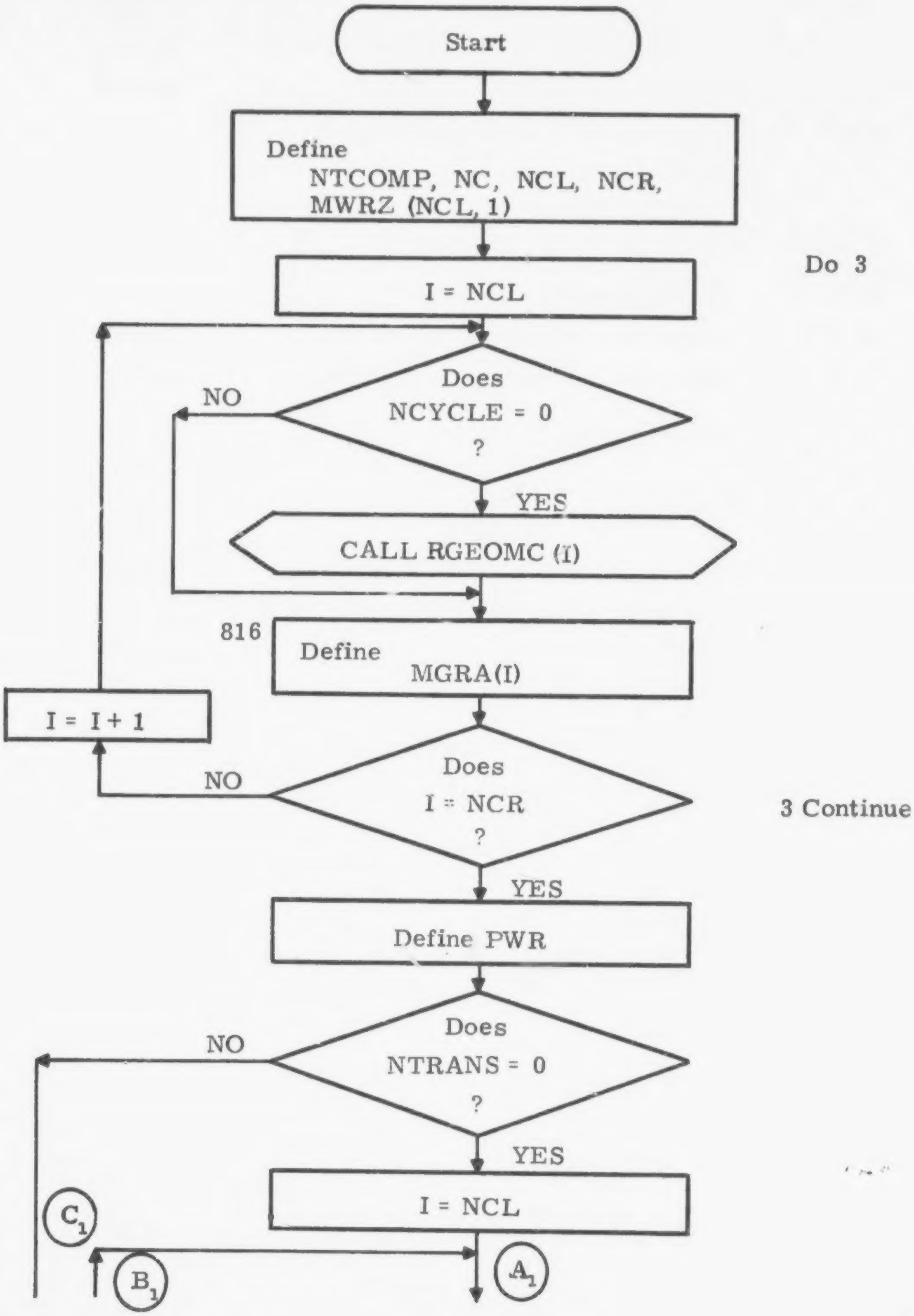
FORTRAN Variable	Definition	Units
MGE	Mass flow rate of gas (vapor) at exit	lb/sec
MGI	Mass flow rate of gas at inlet	lb/sec
NST	Logic variable for transient start 0 - steady-state case 1 - transient case	--
PGRE	Pressure of gas at exit	lb/in.^{2}
PGRI	Pressure of gas at inlet	lb/in.^{2}
PWRE	Pressure of working fluid at exit	lb/in.^{2}
PWRI	Pressure of working fluid at inlet	lb/in.^{2}

Other Selected FORTRAN Variables:

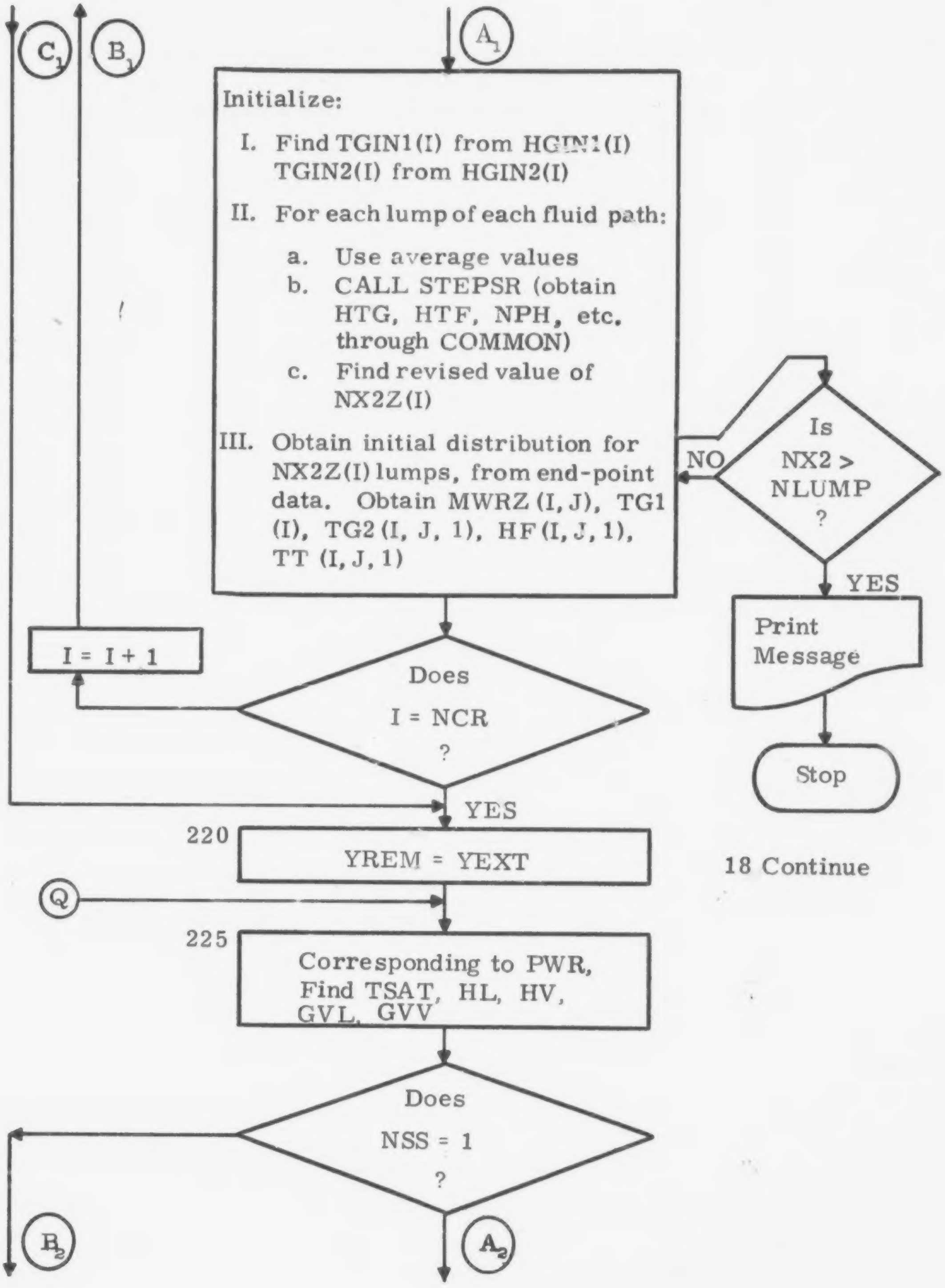
FORTRAN Variable	Definition	Units
MGRZ(I)	Gas mass flow rate for fluid pass I	lb/sec
MWRZ(I, J)	Fluid mass flow rate for fluid pass I at node J	lb/sec
PWR	Fluid pressure	lb/in.^{2}

Note: For the remainder of these variables see "Other Selected FORTRAN Variables" for VAPORG, in Section 6.

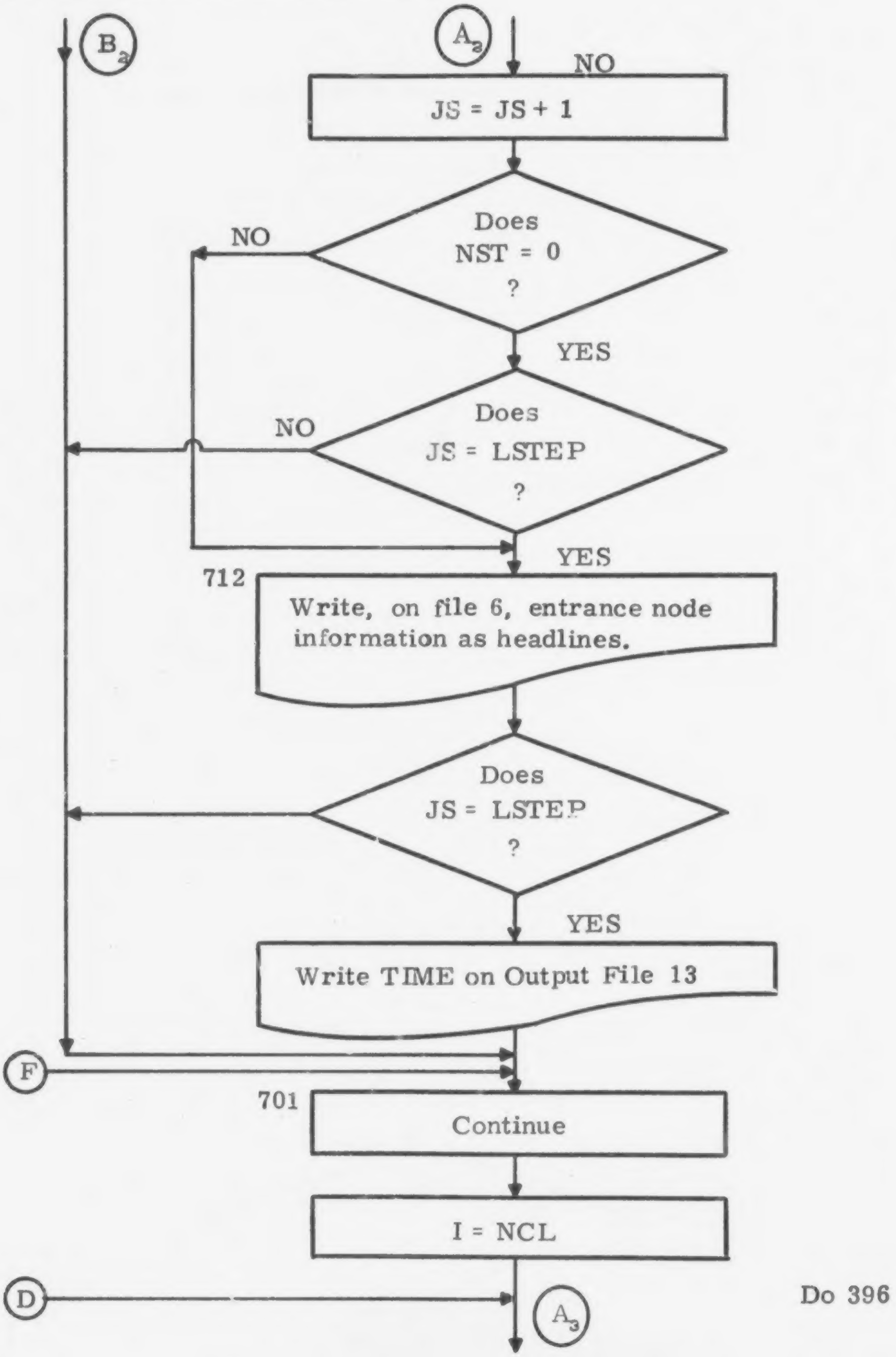
FLOW DIAGRAM -- REGEN


Start
Define
NTCOMP, NC, NCL, NCR,
MWRZ (NCL, 1)
I = NCL
Do 3
Does
NCYCLE = 0
?
NO
YES
CALL RGEOMC (I)
816
Define
MGRA(I)
I = I + 1
Does
I = NCR
?
NO
3 Continue
YES
Define PWR
Does
NTRANS = 0
?
NO
YES
I = NCL
C_1
B_1
A_1

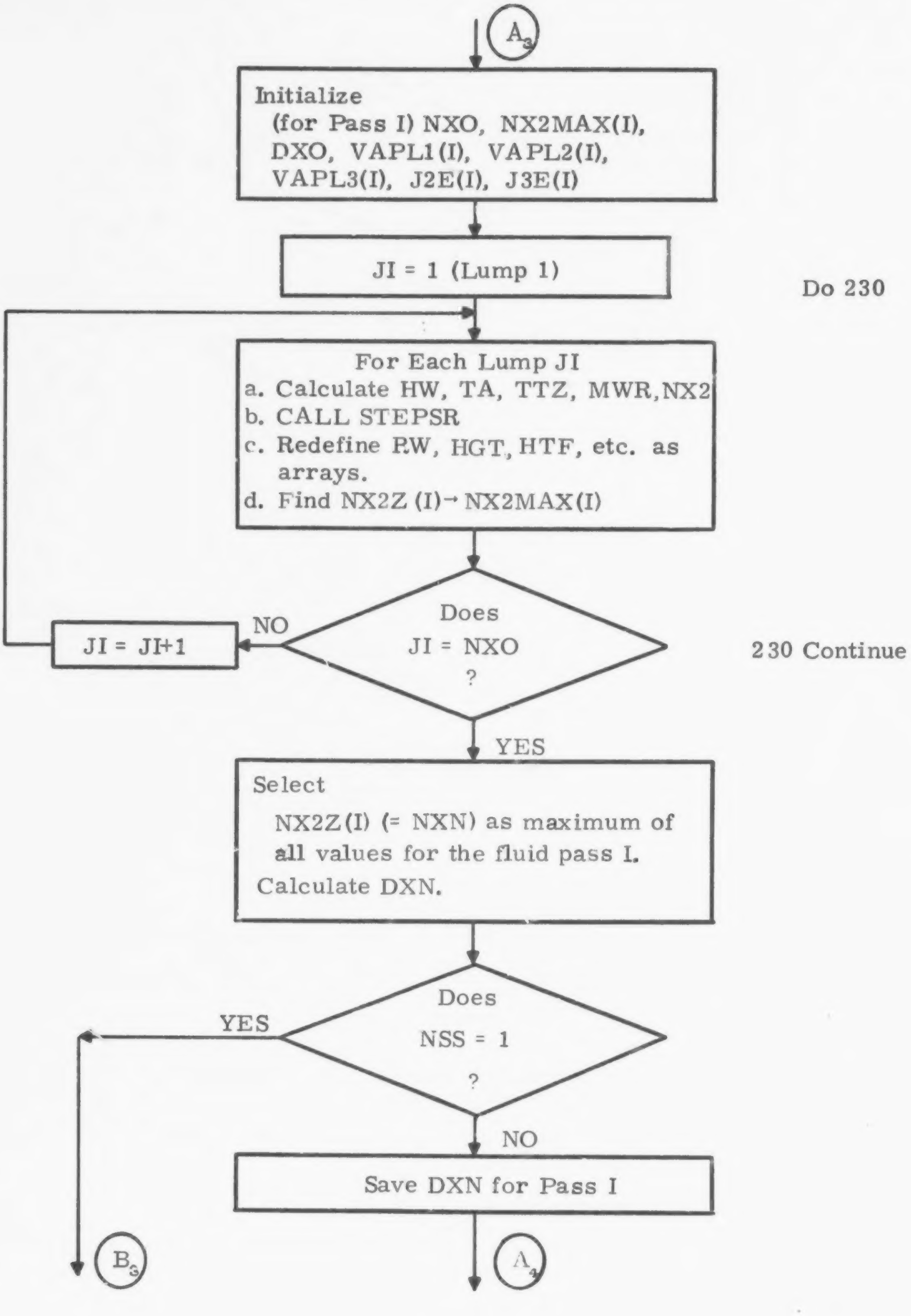
FLOW DIAGRAM -- REGEN (Cont'd)


C1
B1
A1
Initialize:
I. Find TGIN1(I) from HGIN1(I)
TGIN2(I) from HGIN2(I)
II. For each lump of each fluid path:
a. Use average values
b. CALL STEPSR (obtain HTG, HTF, NPH, etc. through COMMON)
c. Find revised value of NX2Z(I)
III. Obtain initial distribution for NX2Z(I) lumps, from end-point data. Obtain MWRZ (I, J), TG1 (I), TG2 (I, J, 1), HF (I, J, 1), TT (I, J, 1)
NO
Is NX2 > NLUMP ?
YES
Print Message
Stop
I = I + 1
Does I = NCR ?
YES
220
YREM = YEXT
18 Continue
Q
225
Corresponding to PWR, Find TSAT, HL, HV, GVL, GVV
Does NSS = 1 ?
B2
A2

FLOW DIAGRAM -- REGEN (Cont'd)

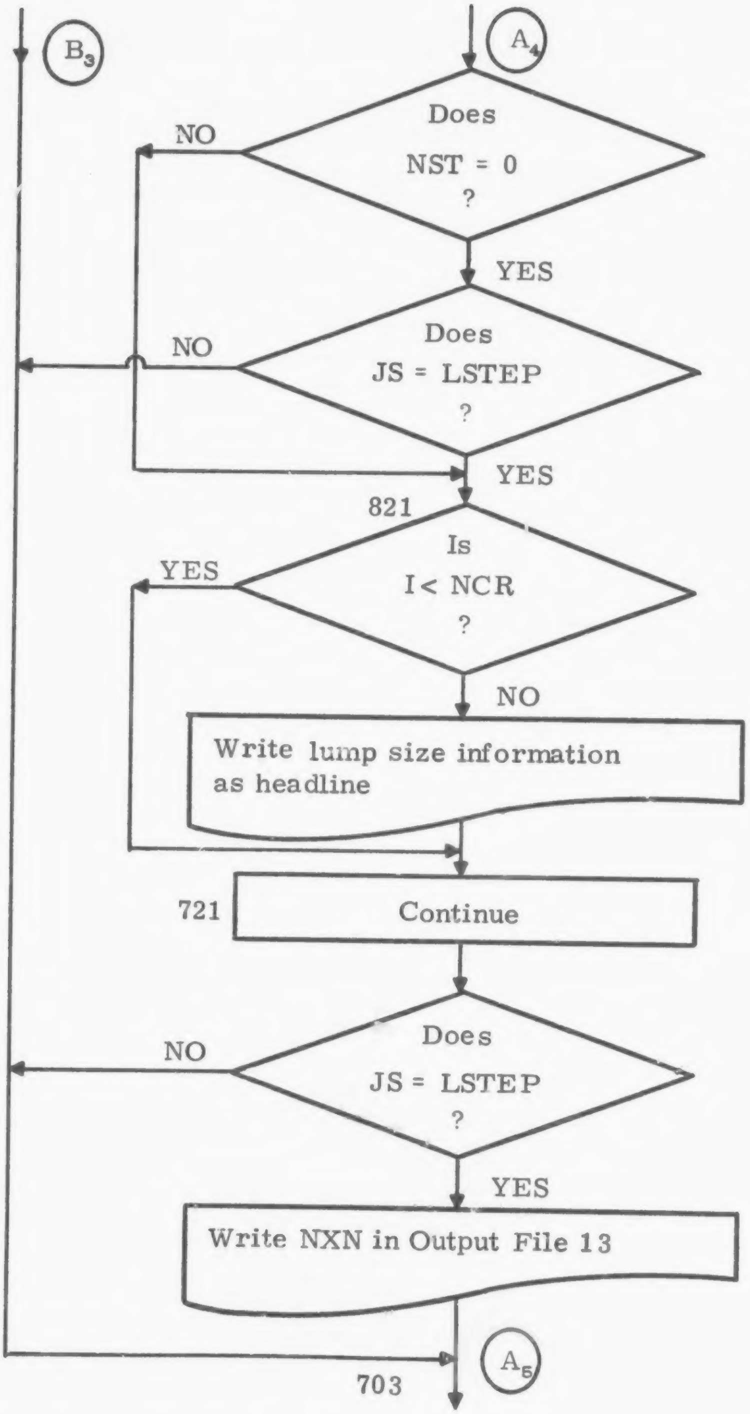

B2
A2
NO
JS = JS + 1
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
712
Write, on file 6, entrance node information as headlines.
Does JS = LSTEP ?
YES
Write TIME on Output File 13
F
701
Continue
I = NCL
D
A3
Do 396

FLOW DIAGRAM -- REGEN (Cont'd)

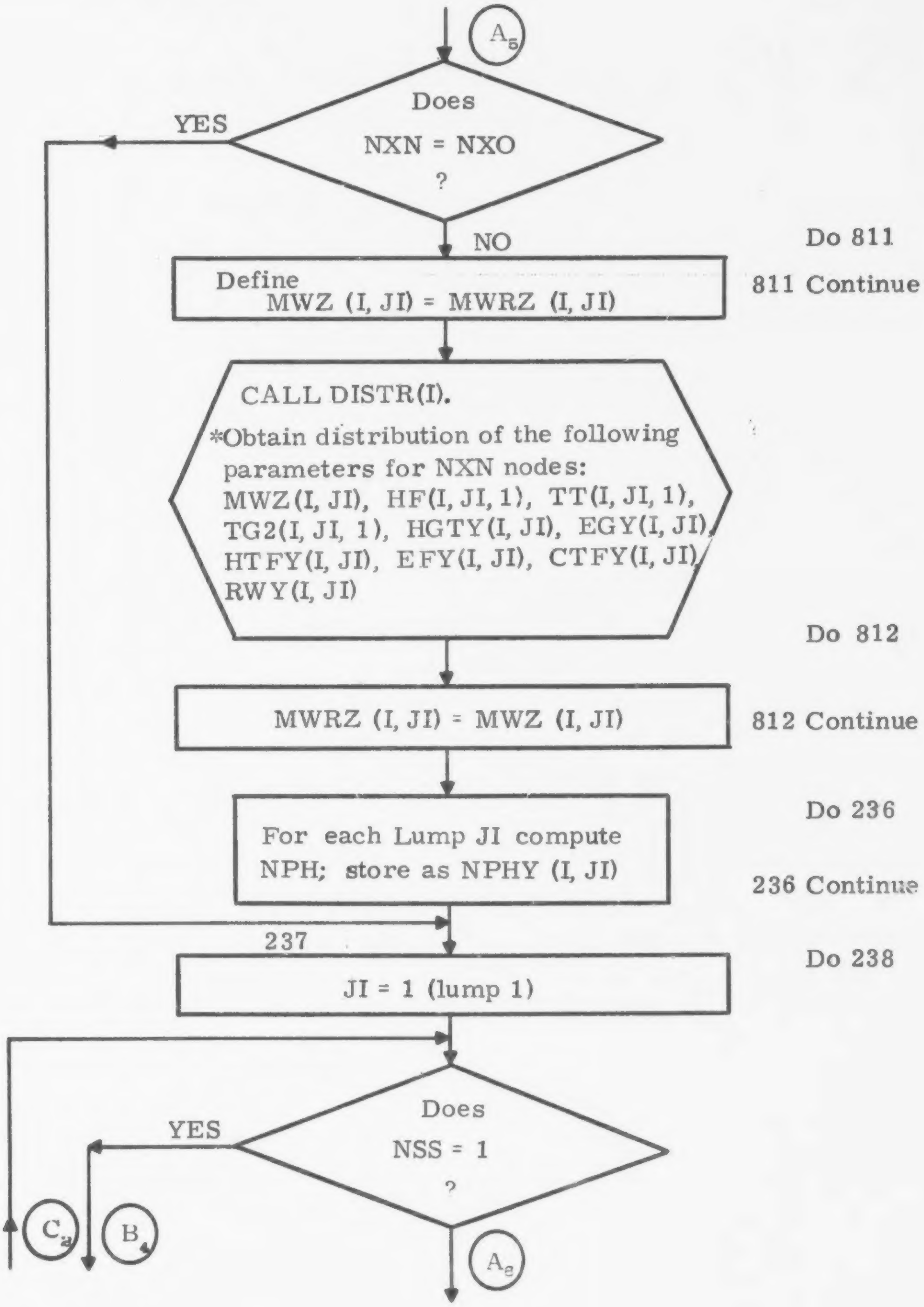


A_3
Initialize
(for Pass I) NXO, NX2MAX(I), DXO, VAPL1(I), VAPL2(I), VAPL3(I), J2E(I), J3E(I)
JI = 1 (Lump 1)
Do 230
For Each Lump JI
a. Calculate HW, TA, TTZ, MWR, NX2
b. CALL STEPSR
c. Redefine PW, HGT, HTF, etc. as arrays.
d. Find NX2Z (I) → NX2MAX(I)
Does JI = NXO ?
NO
JI = JI+1
230 Continue
YES
Select
NX2Z (I) (= NXN) as maximum of all values for the fluid pass I.
Calculate DXN.
Does NSS = 1 ?
YES
NO
Save DXN for Pass I
B_3
A_4

FLOW DIAGRAM -- REGEN (Cont'd)

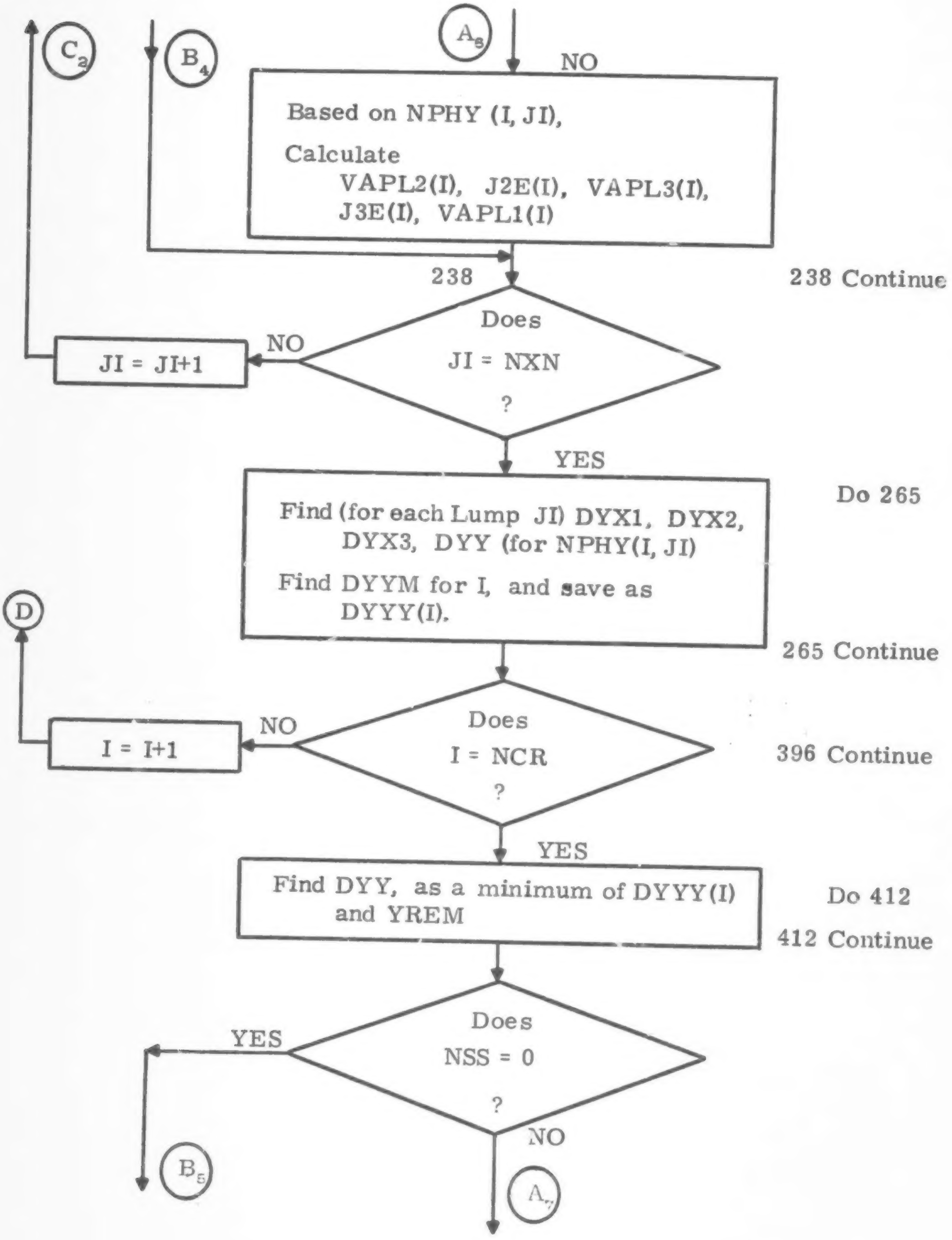

B3
A4
Does
NST = 0
?
NO
YES
Does
JS = LSTEP
?
NO
YES
821
Is
I< NCR
?
YES
NO
Write lump size information as headline
721
Continue
Does
JS = LSTEP
?
NO
YES
Write NXN in Output File 13
A5
703

FLOW DIAGRAM -- REGEN (Cont'd)

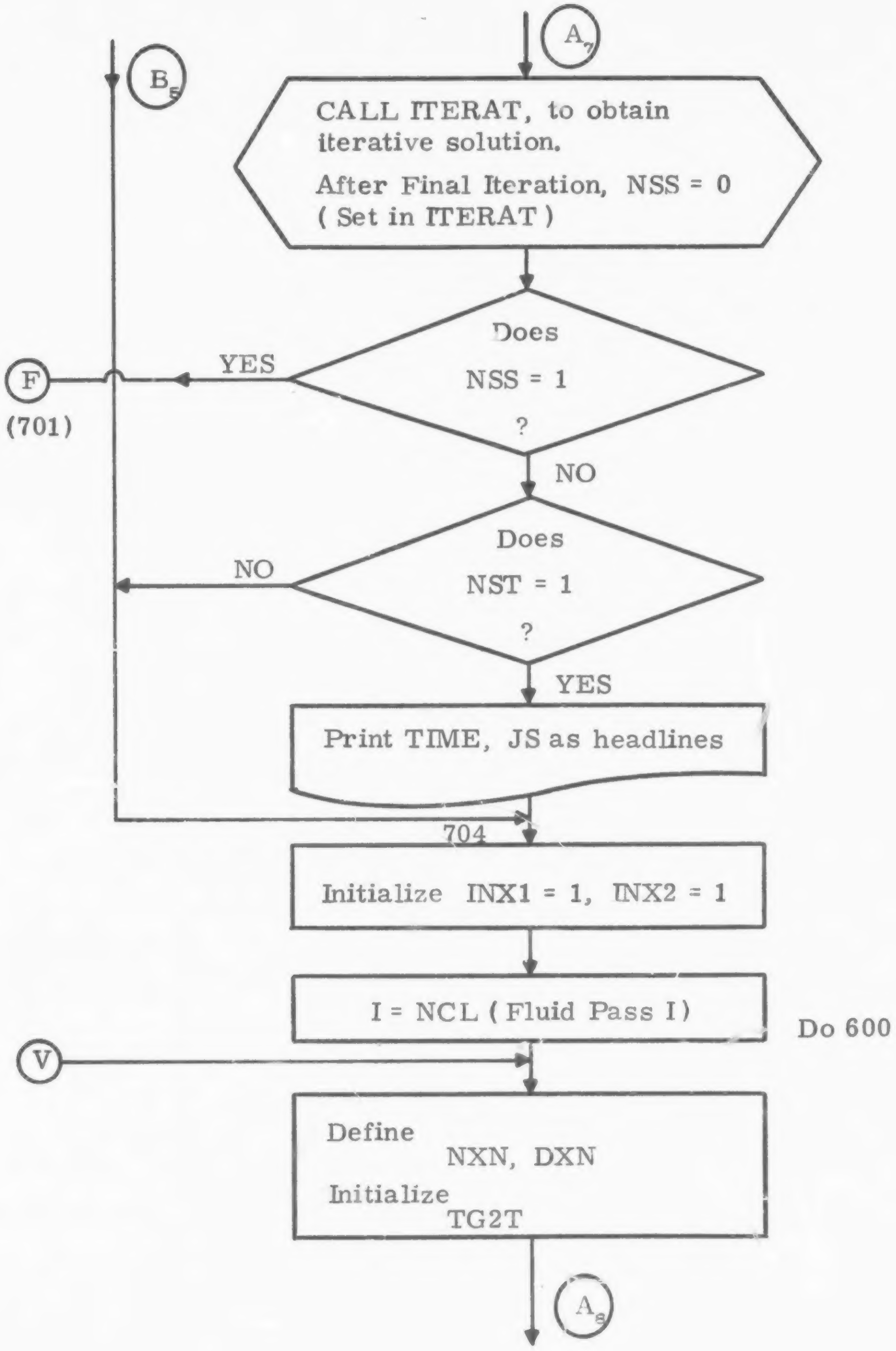


A5
Does
NXN = NXO
?
YES
NO
Do 811
Define
MWZ (I, JI) = MWRZ (I, JI)
811 Continue
CALL DISTR(I).
*Obtain distribution of the following parameters for NXN nodes:
MWZ(I, JI), HF(I, JI, 1), TT(I, JI, 1), TG2(I, JI, 1), HGTY(I, JI), EGY(I, JI), HTFY(I, JI), EFY(I, JI), CTFY(I, JI), RWY(I, JI)
Do 812
MWRZ (I, JI) = MWZ (I, JI)
812 Continue
Do 236
For each Lump JI compute NPH; store as NPHY (I, JI)
236 Continue
237
Do 238
JI = 1 (lump 1)
Does
NSS = 1
?
YES
C2
B4
A8

FLOW DIAGRAM -- REGEN (Cont'd)

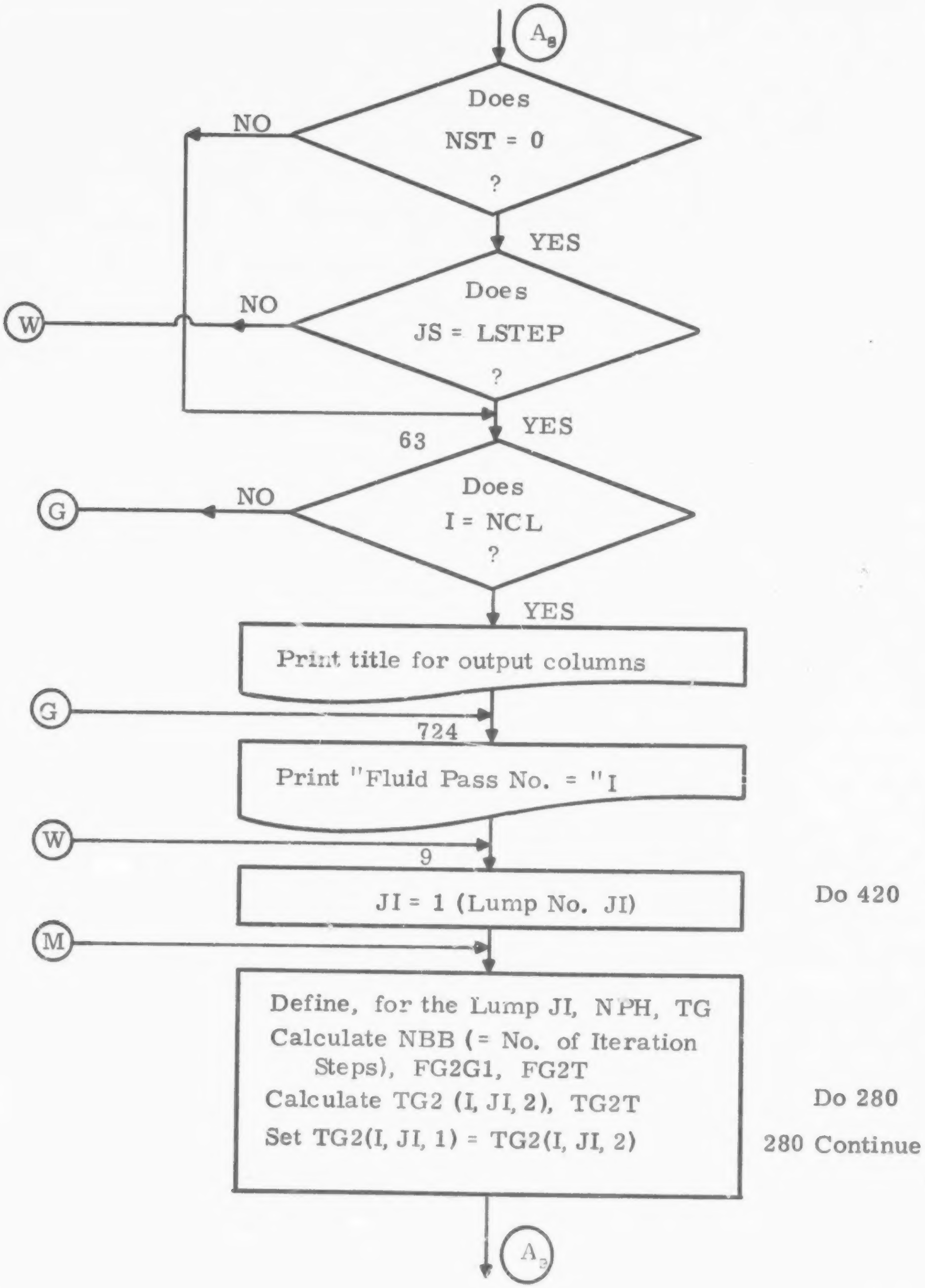

C2
B4
A8
NO
Based on NPHY (I, JI),
Calculate
VAPL2(I), J2E(I), VAPL3(I),
J3E(I), VAPL1(I)
238
238 Continue
Does
JI = NXN
?
NO
JI = JI+1
YES
Do 265
Find (for each Lump JI) DYX1, DYX2, DYX3, DYY (for NPHY(I, JI)
Find DYYM for I, and save as DYYY(I).
265 Continue
D
Does
I = NCR
?
NO
I = I+1
396 Continue
YES
Find DYY, as a minimum of DYYY(I) and YREM
Do 412
412 Continue
Does
NSS = 0
?
YES
NO
B5
A7

FLOW DIAGRAM -- REGEN (Cont'd)

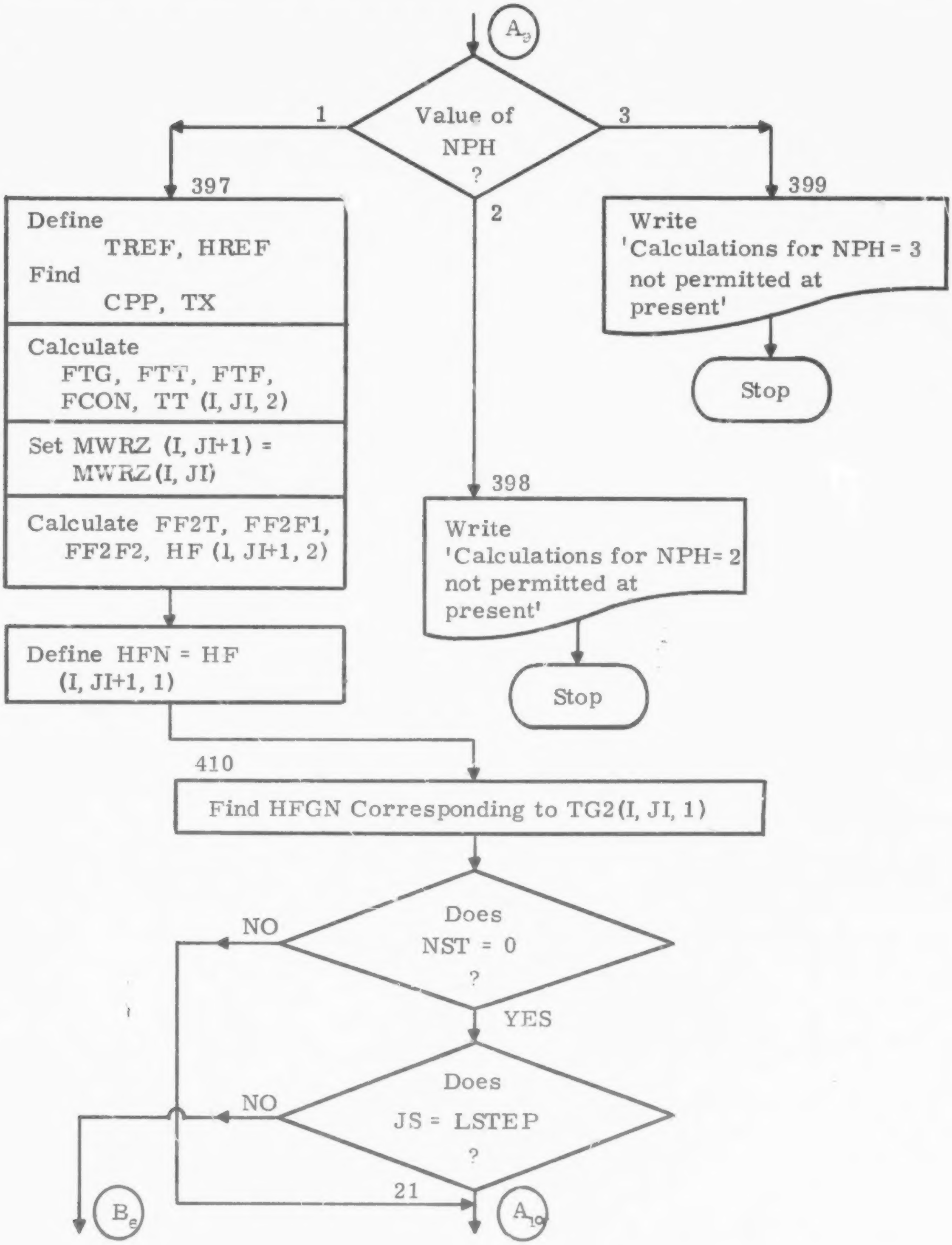


A7
B5
CALL ITERAT, to obtain iterative solution.
After Final Iteration, NSS = 0
(Set in ITERAT)
Does NSS = 1 ?
YES
F
(701)
NO
Does NST = 1 ?
NO
YES
Print TIME, JS as headlines
704
Initialize INX1 = 1, INX2 = 1
I = NCL (Fluid Pass I)
Do 600
V
Define NXN, DXN
Initialize TG2T
A8

FLOW DIAGRAM -- REGEN (Cont'd)

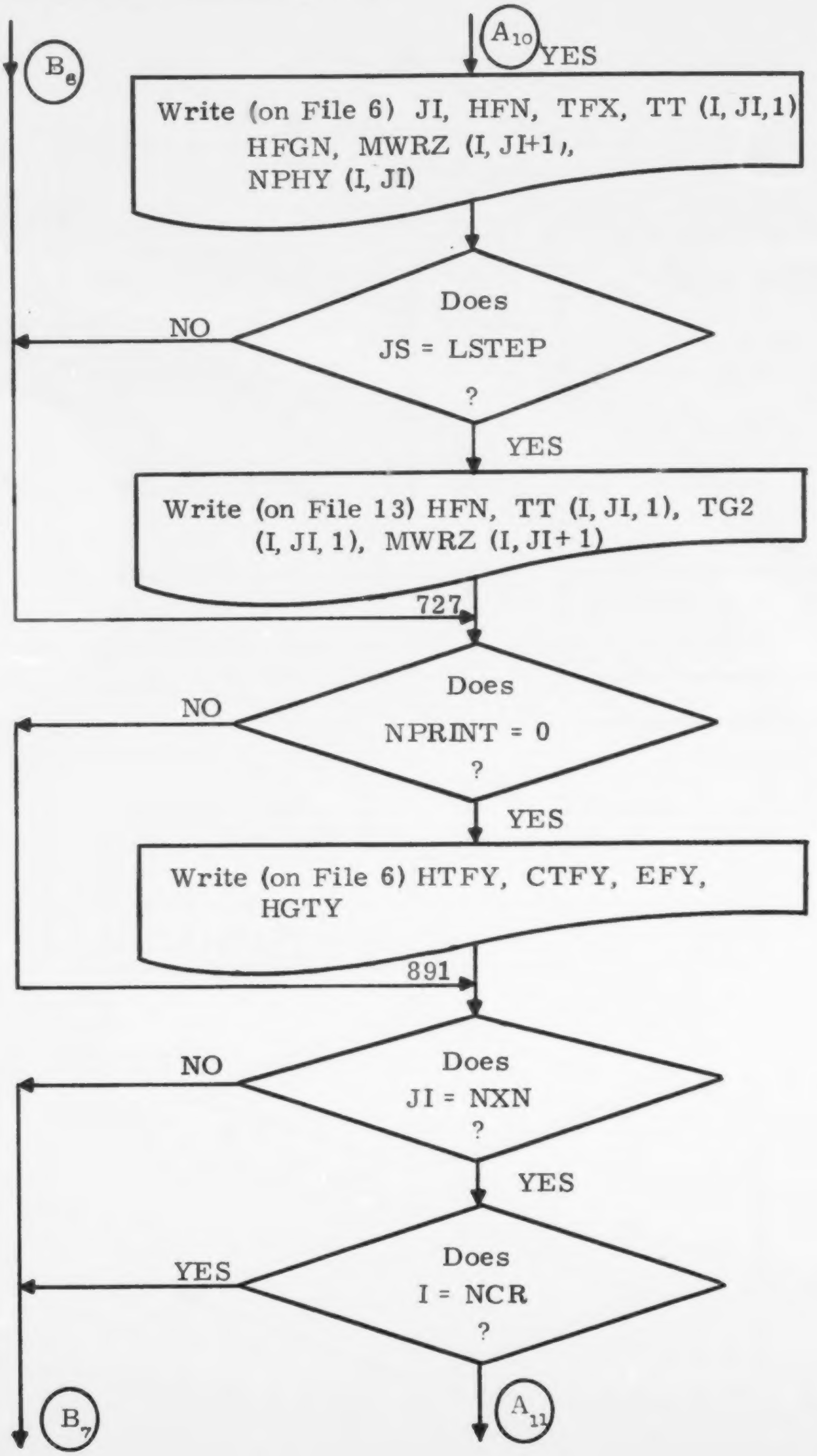

A_8
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
W
YES
63
Does I = NCL ?
NO
G
YES
Print title for output columns
G
724
Print "Fluid Pass No. = "I
W
9
JI = 1 (Lump No. JI)
Do 420
M
Define, for the Lump JI, NPH, TG
Calculate NBB (= No. of Iteration Steps), FG2G1, FG2T
Calculate TG2 (I, JI, 2), TG2T
Set TG2(I, JI, 1) = TG2(I, JI, 2)
Do 280
280 Continue
A_9

FLOW DIAGRAM -- REGEN (Cont'd)



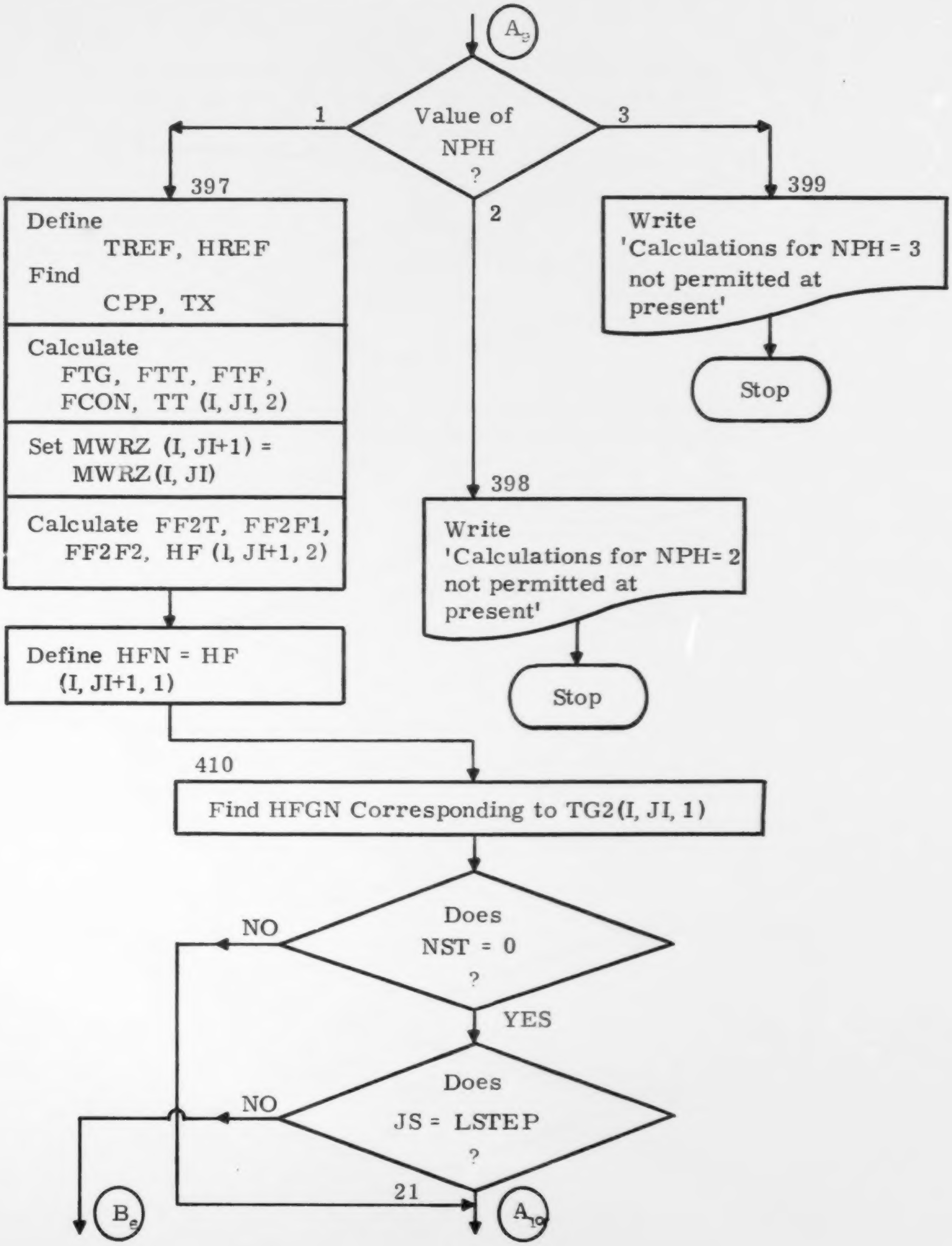
A_9
Value of NPH ?
1
2
3
397
Define TREF, HREF
Find CPP, TX
Calculate FTG, FTT, FTF, FCON, TT (I, JI, 2)
Set MWRZ (I, JI+1) = MWRZ(I, JI)
Calculate FF2T, FF2F1, FF2F2, HF (I, JI+1, 2)
Define HFN = HF (I, JI+1, 1)
399
Write 'Calculations for NPH = 3 not permitted at present'
Stop
398
Write 'Calculations for NPH= 2 not permitted at present'
Stop
410
Find HFGN Corresponding to TG2(I, JI, 1)
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
21
B_9
A_{10}

FLOW DIAGRAM -- REGEN (Cont'd)



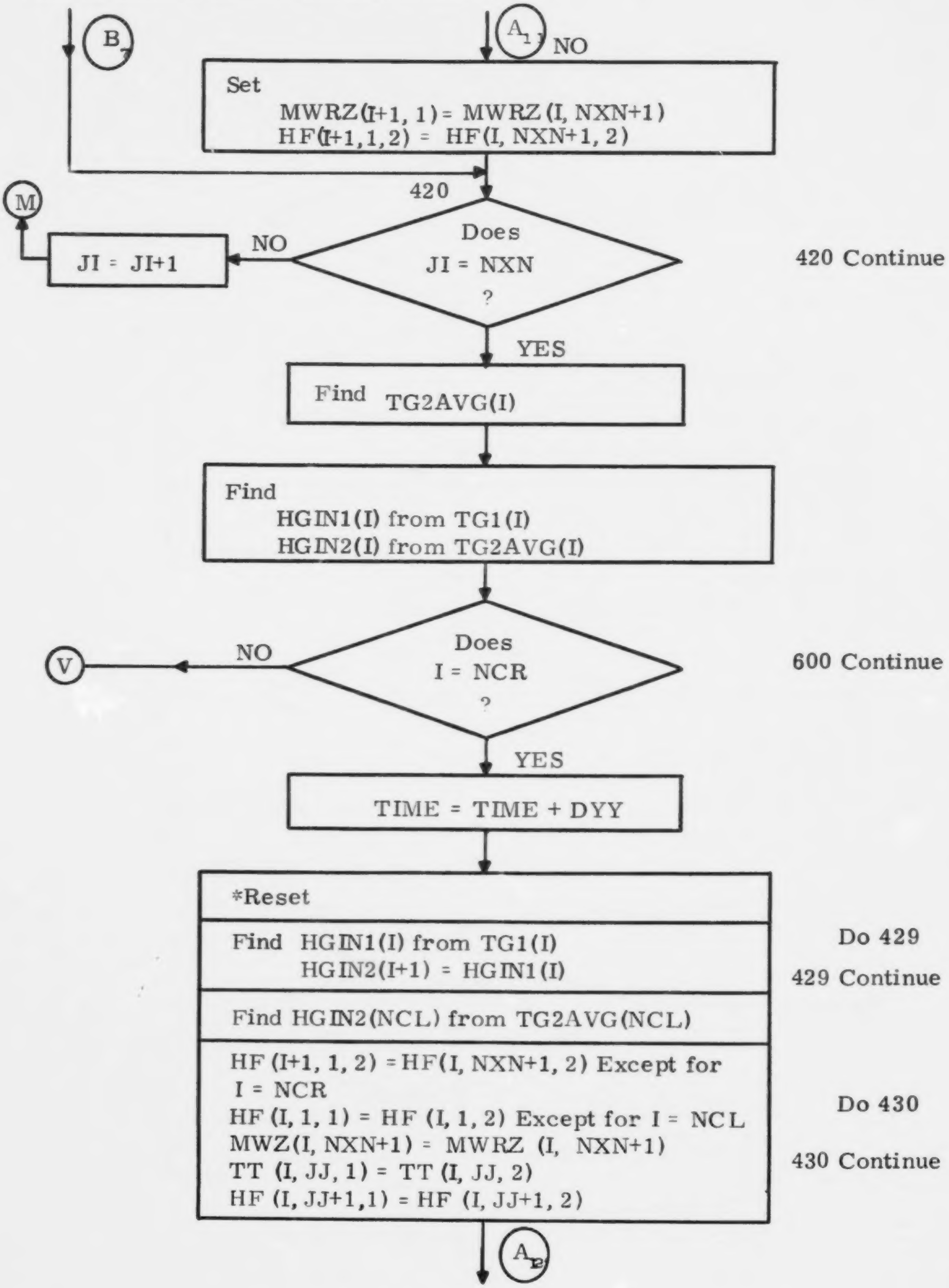
A_{10}
YES
B_8
Write (on File 6) JI, HFN, TFX, TT (I, JI,1) HFGN, MWRZ (I, JI+1), NPHY (I, JI)
Does JS = LSTEP ?
NO
YES
Write (on File 13) HFN, TT (I, JI, 1), TG2 (I, JI, 1), MWRZ (I, JI+1)
727
Does NPRINT = 0 ?
NO
YES
Write (on File 6) HTFY, CTFY, EFY, HGTY
891
Does JI = NXN ?
NO
YES
Does I = NCR ?
YES
B_7
A_{11}

FLOW DIAGRAM -- REGEN (Cont'd)

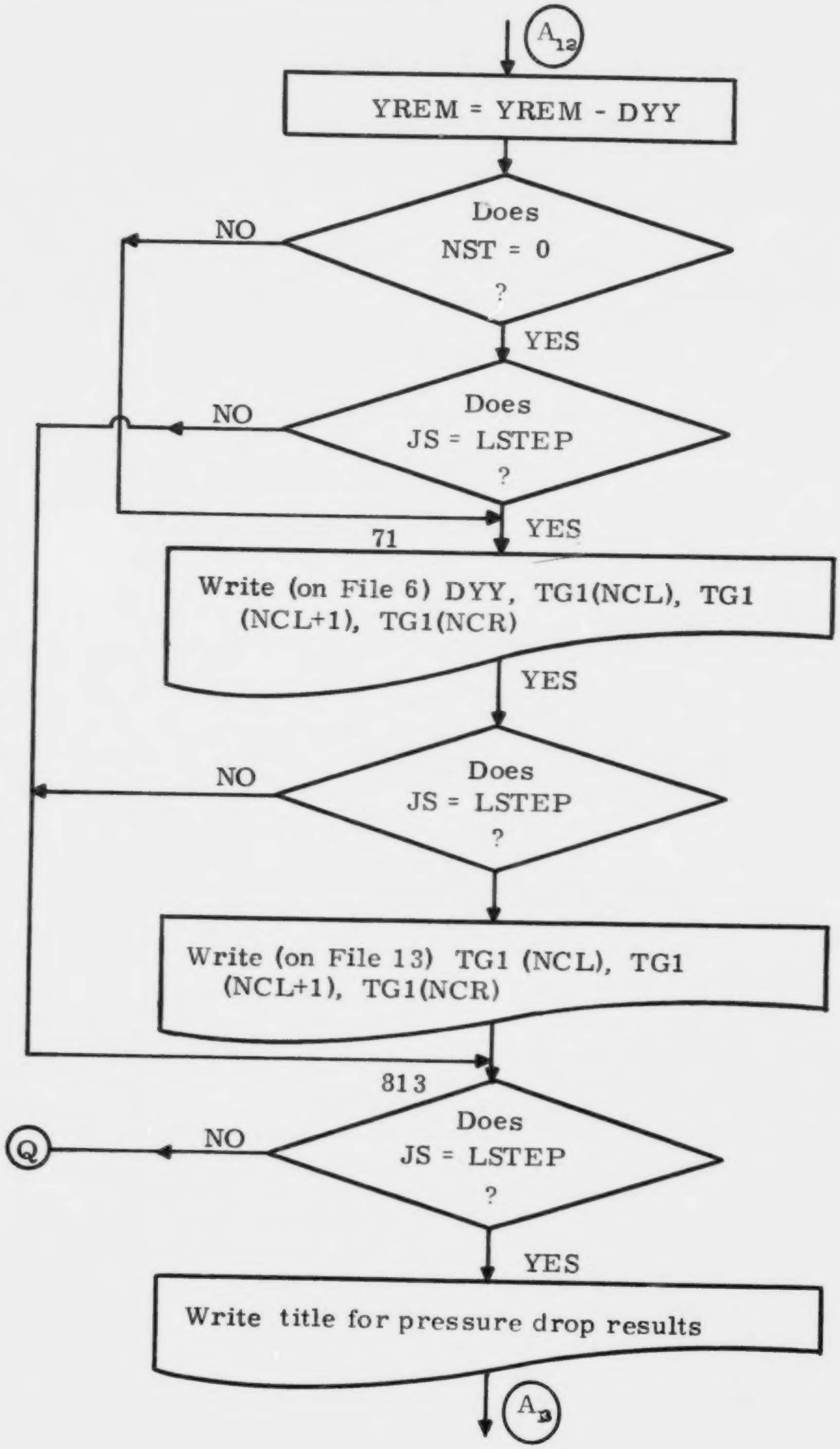


A_9
Value of NPH ?
1
2
3
397
Define TREF, HREF
Find CPP, TX
Calculate FTG, FTT, FTF, FCON, TT (I, JI, 2)
Set MWRZ (I, JI+1) = MWRZ (I, JI)
Calculate FF2T, FF2F1, FF2F2, HF (l, JI+1, 2)
Define HFN = HF (I, JI+1, 1)
398
Write 'Calculations for NPH= 2 not permitted at present'
Stop
399
Write 'Calculations for NPH = 3 not permitted at present'
Stop
410
Find HFGN Corresponding to TG2 (I, JI, 1)
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
21
B_9
A_{10}

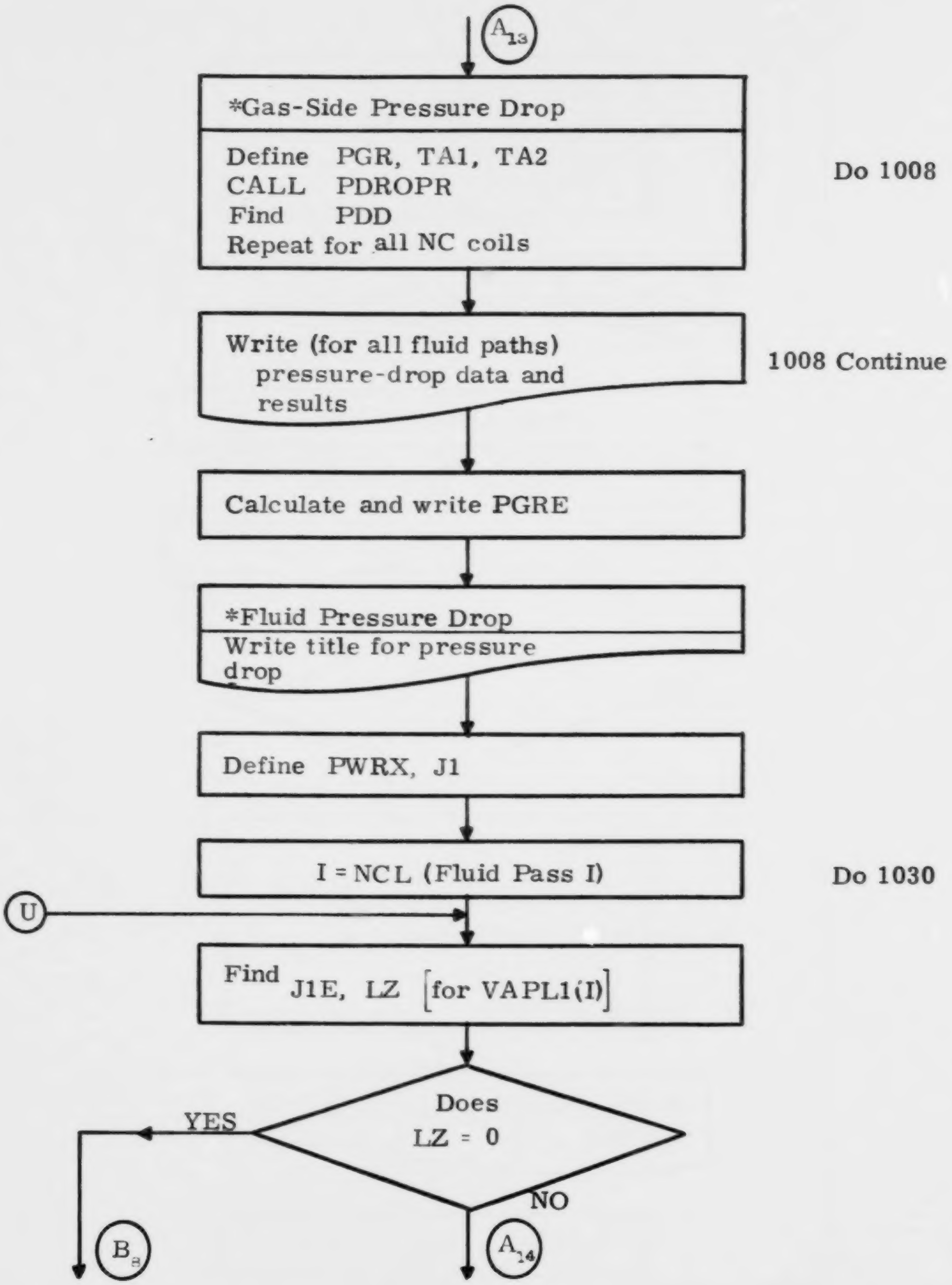
FLOW DIAGRAM -- REGEN (Cont'd)


B
A1
NO
Set
MWRZ(I+1, 1) = MWRZ(I, NXN+1)
HF(I+1,1,2) = HF(I, NXN+1, 2)
420
M
JI = JI+1
NO
Does
JI = NXN
?
420 Continue
YES
Find TG2AVG(I)
Find
HGIN1(I) from TG1(I)
HGIN2(I) from TG2AVG(I)
V
NO
Does
I = NCR
?
600 Continue
YES
TIME = TIME + DYY
*Reset
Find HGIN1(I) from TG1(I)
HGIN2(I+1) = HGIN1(I)
Do 429
429 Continue
Find HGIN2(NCL) from TG2AVG(NCL)
HF (I+1, 1, 2) = HF(I, NXN+1, 2) Except for I = NCR
HF (I, 1, 1) = HF (I, 1, 2) Except for I = NCL
MWZ(I, NXN+1) = MWRZ (I, NXN+1)
TT (I, JJ, 1) = TT (I, JJ, 2)
HF (I, JJ+1,1) = HF (I, JJ+1, 2)
Do 430
430 Continue
A2

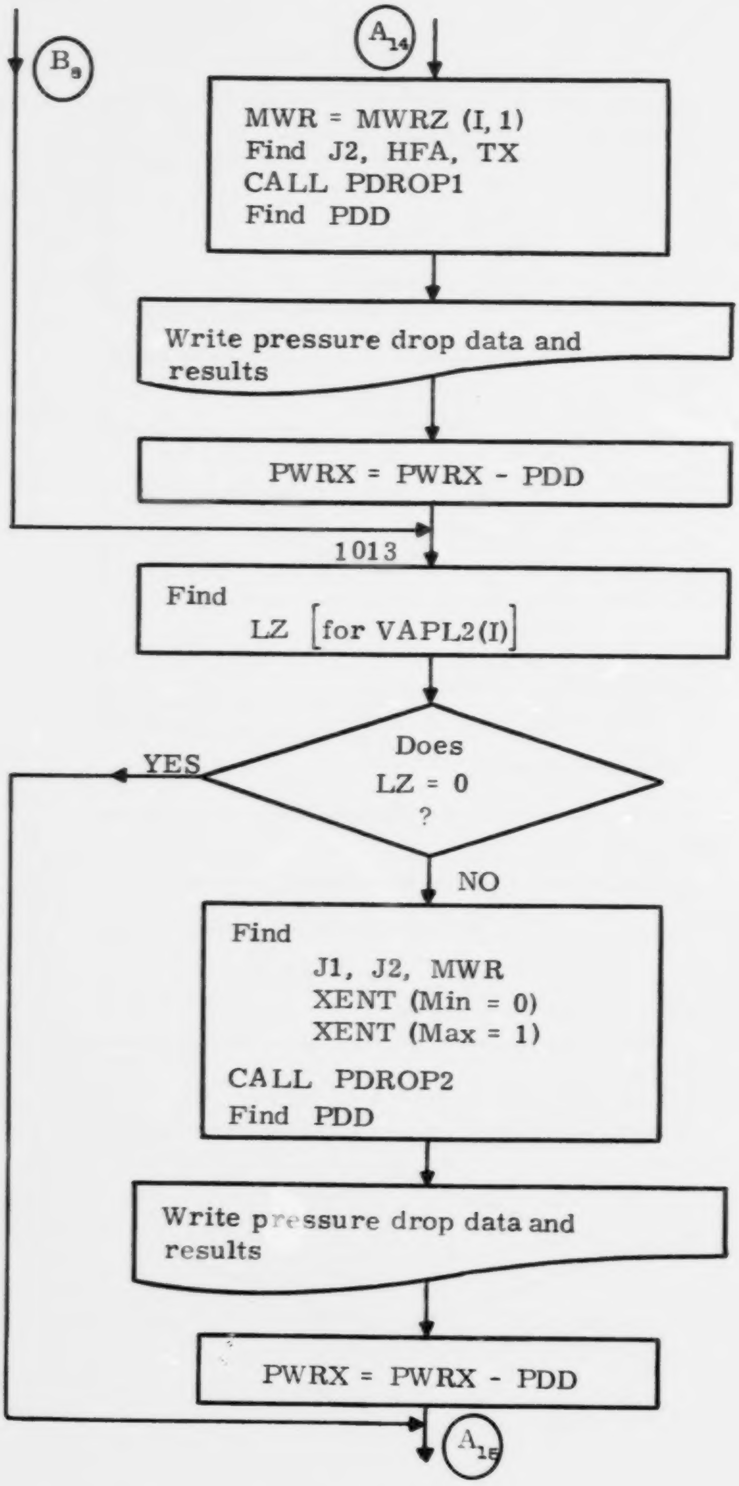
FLOW DIAGRAM -- REGEN (Cont'd)


A12
YREM = YREM - DYY
Does NST = 0 ?
NO
YES
Does JS = LSTEP ?
NO
YES
71
Write (on File 6) DYY, TG1(NCL), TG1 (NCL+1), TG1(NCR)
YES
Does JS = LSTEP ?
NO
Write (on File 13) TG1 (NCL), TG1 (NCL+1), TG1(NCR)
813
Does JS = LSTEP ?
NO
Q
YES
Write title for pressure drop results
A13

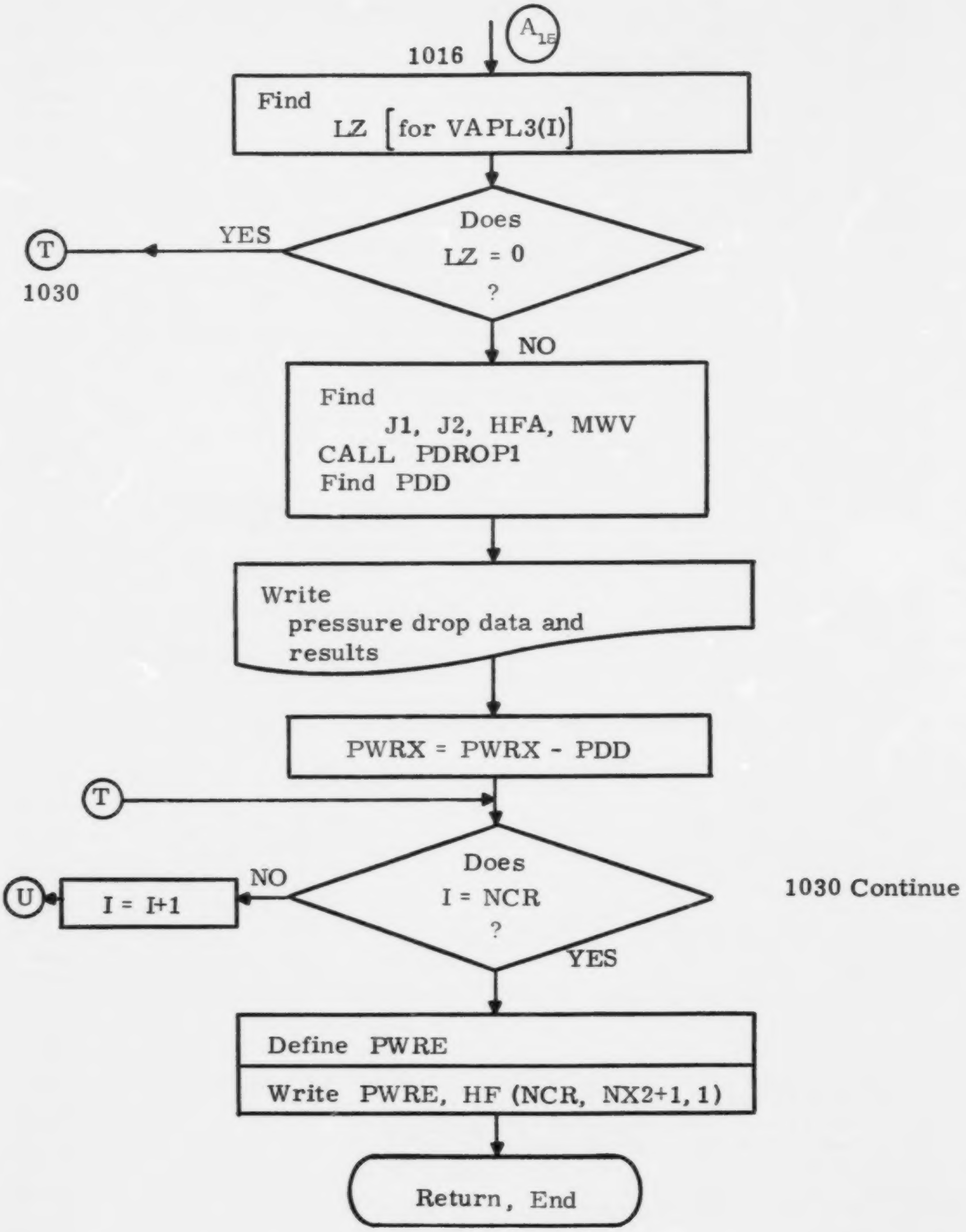
FLOW DIAGRAM -- REGEN (Cont'd)


A_{13}
*Gas-Side Pressure Drop
Define PGR, TA1, TA2
CALL PDROPR
Find PDD
Repeat for all NC coils
Do 1008
Write (for all fluid paths) pressure-drop data and results
1008 Continue
Calculate and write PGRE
*Fluid Pressure Drop
Write title for pressure drop
Define PWRX, J1
I = NCL (Fluid Pass I)
Do 1030
U
Find J1E, LZ [for VAPL1(I)]
Does LZ = 0
YES
NO
B_8
A_{14}

FLOW DIAGRAM -- REGEN (Cont'd)


B9
A14
MWR = MWRZ (I, 1)
Find J2, HFA, TX
CALL PDROP1
Find PDD
Write pressure drop data and results
PWRX = PWRX - PDD
1013
Find
LZ [for VAPL2(I)]
Does
LZ = 0
?
YES
NO
Find
J1, J2, MWR
XENT (Min = 0)
XENT (Max = 1)
CALL PDROP2
Find PDD
Write pressure drop data and results
PWRX = PWRX - PDD
A15

FLOW DIAGRAM -- REGEN (Cont'd)


A15
1016
Find
LZ [for VAPL3(I)]
Does
LZ = 0
?
YES
T
1030
NO
Find
J1, J2, HFA, MWV
CALL PDROP1
Find PDD
Write
pressure drop data and
results
PWRX = PWRX - PDD
T
Does
I = NCR
?
NO
I = I+1
U
YES
1030 Continue
Define PWRE
Write PWRE, HF (NCR, NX2+1, 1)
Return, End

PROGRAM LISTING -- REGEN

```
      SUBROUTINE REGEN(MGI,MGE,PGRI,PGRE,PWRI,PWRE,HGRI,JS,NST)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCI,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2F(10),J3F(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),INO
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL    L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      DIMENSION GV2(10),GV2N(10),MGRZ(10),MGRA(10),MWRZ(10,11)
      DIMENSION PGR(10)
      REAL LZ,MEN1,MGE,MGI,MGR,MGRA,MGRZ,MWR,MWRZ
      NTCOMP=3
      NC=NCY(NTCOMP)
      NCL=NCLY(NTCOMP)
      NCR=NCRY(NTCOMP)
      MWRZ(NCL,1)=MWZ(NCL,1)
      DO 3 I=NCL,NCR
      IF(NCYCLE.NE.0) GO TO 816
      CALL RGEOMC(I)
 816  CONTINUE
      MGRA(I)=MGI/(12.*L(I))
   3  CONTINUE
      PWR=PWRI
      IF(NTRANS.NE.0) GO TO 220
*     INITIALIZE
      DO 18 I=NCL,NCR
      NX2Z(I)=1
*     ASSUME AVERAGE VALUES,STATE RELATIONSHIPS NOT IMPORTANT
      IF(I.EQ.NCR) HGIN1(I)=HGRI
      CALL SUPPT(PGRI,TGIN1(I),HGIN1(I),DD,DD,3)
      CALL SUPPT(PGRI,TGIN2(I),HGIN2(I),DD,DD,3)
      A1=12.*L(I)
      HG=(HGIN1(I)+HGIN2(I))/2.
      CALL SUPPT(PGRI,TG,HG,DD,DD,3)
      TTZ=TG-10.
      NX2=NX2Z(I)
```

PROGRAM LISTING -- REGEN (Cont'd)

```
      HW=0.5*(HFIN1(I)+HFIN2(I))
      CALL STEPSR(PWR,TW,HW,PGRI,TG,TTZ,MWRZ(NCL,1),MGRA(I),XF,
     7I,A1,NX2)
      IF(NX2.LE.NLUMP) GO TO 15
   10 FORMAT(35H NO. OF LUMP REQUIRED EXCEEDS NLUMP)
      WRITE(6,10)
      WRITE(6,2)NX2
    2 FORMAT(6H NX2  ,I10)
      STOP
   15 NX2Z(I)=NX2
*     INITIAL DISTRIBUTION
      TT(I,1,1)=TTZ
      IF(I.NE.NCL) HF(I,1,1)=HFIN1(I)
      TG1(I)=TGIN1(I)
      TG2(I,1,1)=TGIN2(I)
      XN2Z=FLOAT(NX2)
      DXN=12.*L(I)/XN2Z
      A2=(HFIN2(I)-HFIN1(I))/XN2Z
      MWRZ(I,1)=MWRZ(NCL,1)
      DO 18 J=1,NX2
      MWRZ(I,J+1)=MWRZ(NCL,1)
      HF(I,J+1,1)=HF(I,J,1)+A2
      TT(I,J,1)=TT(I,1,1)
*     NOTE DO NOT USE TG2,TT AT NX2+1
      TG2(I,J,1)=TGIN2(I)
   18 CONTINUE
*     ENTRY POINT AFTER FIRST CYCLE
  220 YREM=YEXT
*     AT THIS POINT THE EXTERNAL CONDITIONS ARE ENTERED FOR
*     THE NEXT EXTERNAL TIME STEP.  DURING INITIALIZATION
*     THEY SHOULD BE MADE EQUAL TO THE INITIALIZING VALUES
*     PWR FROM PRESSURE COMPUTATION
      CALL SUPPT(PGRI,TG1(NCR),HGRI,S,GVRI,3)
*     THE FOLLOWING IS A LOOP BACK FROM STATEMENT 1000-1
  225 CONTINUE
      CALL SATP(PWR,TSAT,GVL,GVV,HL,HV,1)
      IF(NSS.EQ.1) GO TO 701
      JS=JS+1
      IF(NST.NE.0) GO TO 712
      IF(JS.NE.LSTEP) GO TO 701
  712 WRITE(6,713)TIME,JS
  713 FORMAT(40H                              ***** TIME = ,E15.5,
     721H          (TIMESTEP NO.,I5,2H ))
      WRITE(6,5029)
      WRITE(6,715)HF(NCL,1,1)
  715 FORMAT(29H FLUID ENTHALPY (ENTRANCE)  =,F15.5)
      WRITE(6,716)MWRZ(NCL,1)
  716 FORMAT(29H FLUID FLOW RATE (ENTRANCE) =,F15.5)
      WRITE(6,720)PWR,TSAT
  720 FORMAT(29H FLUID PRESSURE, SAT. TEMP  =,2E15.5)
      WRITE(6,817)MGI
  817 FORMAT(29H GAS FLOW RATE (ENTRANCE)   =,F15.5)
      WRITE(6,818)PGRI,HGRI
  818 FORMAT(29H GAS PRES, ENTH (ENTRANCE)  =,2E15.5)
      IF(JS.NE.LSTEP) GO TO 701
      WRITE(13,719)TIME
  719 FORMAT(E15.5)
  701 CONTINUE
      DO 396 I=NCL,NCR
      NXO=NX2Z(I)
```

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PROGRAM LISTING -- REGEN (Cont'd)

```
      NX2MAX(I)=1
      VAPL1(I)=0.
      VAPL2(I)=0.
      VAPL3(I)=0.
      J2F(I)=0
      J3E(I)=0
      DX0=12.*L(I)/FLOAT(NX0)
      DO 230 JI=1,NX0
      HW=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      TA=(TG1(I)+TG2(I,JI,1))/2.
      TTZ=TT(I,JI,1)
      A1=L(I)*12.
      MWR=MWRZ(I,JI)
      NX2=NX2Z(I)
      CALL STEPSR(PWR,TW,HW,PGRI,TA,TTZ,MWR,MGRA(I),XF,I,A1,NX2)
*     THE FOLLOWING ARE AVAILABLE FROM STEPSI AND ARE BULK
      RWY(I,JI)=RW
      HGTY(I,JI)=HGT
      HTFY(I,JI)=HTF
      FFY(I,JI)=FF
      CTFY(I,JI)=CTF
      NPHY(I,JI)=NPH
      NX2MAX(I)=MAX0(NX2MAX(I),NX2)
 230  CONTINUE
      NXN=NX2MAX(I)
      NX2Z(I)=NXN
      DXN=12.*L(I)/FLOAT(NXN)
      DX2=DXN
      IF(NSS.EQ.1) GO TO 703
      IF(I.EQ.NCL) DXN1=DX2
      IF(I.EQ.(NCL+1)) DXN2=DX2
      IF(I.EQ.(NCL+2)) DXN3=DX2
      IF(NST.NE.0) GO TO 821
      IF(JS.NE.LSTEP) GO TO 703
 821  IF(I.LT.NCR) GO TO 721
      WRITE(6,5)DXN1,DXN2,DXN3,DX2
   5  FORMAT(29H LUMP SIZE (COILS 1,2,3,4)  =,4E15.5)
      WRITE(6,5029)
 721  CONTINUE
      IF(JS.NE.LSTEP) GO TO 703
      WRITE(13,723)NXN
 723  FORMAT(I10)
 703  CONTINUE
      IF(NXN.EQ.NX0) GO TO 237
      MA=NX0+1
      DO 811 JI=1,MA
 811  MWZ(I,JI)=MWRZ(I,JI)
      CALL DISTR(I)
      MA=NXN+1
      DO 812 JI=1,MA
 812  MWRZ(I,JI)=MWZ(I,JI)
      DO 236 JI=1,NXN
      HW=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      IF(HW-HL) 231,232,232
 231  NPH=1
      GO TO 235
 232  IF(HW-HV) 233,233,234
 233  NPH=2
      GO TO 235
 234  NPH=3
```

PROGRAM LISTING -- REGEN (Cont'd)

```
  235 NPHY(I,JI)=NPH
  236 CONTINUE
  237 DO 238  JI=1,NXN
      IF(NSS.EQ.1) GO TO 238
      NPH=NPHY(I,JI)
*     LOCATE INTERPHASES
      IF(NPH-2)229,226,227
  226 VAPL2(I)=VAPL2(I)+(DXO*ACI(I))
      J2E(I)=J2E(I)+1
      GO TO 229
  227 VAPL3(I)=VAPL3(I)+(DXO*ACI(I))
      J3E(I)=J3E(I)+1
  229 VAPL1(I)=12.*ACI(I)*L(I)-VAPL2(I)-VAPL3(I)
      IF(VAPL1(I).LT.DXO*ACI(I)/2.) VAPL1(I)=0.
  238 CONTINUE
      DYYM=YREM
      DO 265 JI=1,NXN
      X2=2.*(FFY(I,JI)/HTFY(I,JI))
      DYX1=CTT(I)/(HGTY(I,JI)+HTFY(I,JI))
      DYX2=(2.*CTFY(I,JI)/HTFY(I,JI))/((X2/DXN)+1.)
      DYX3=ABS(RWY(I,JI)*ACI(I)*DXN/(MWRZ(I,JI)*1728.))
      IF(NPHY(I,JI).EQ.1) DYY=FRAC*AMIN1(DYX1,DYX2)
      IF(NPHY(I,JI).EQ.2) DYY=FRAC*AMIN1(DYX1,DYX3)
      IF(NPHY(I,JI).EQ.3) DYY=FRAC*DYX1
      DYYM=AMIN1(DYYM,DYY)
  265 CONTINUE
      DXN=DX2
      DYYY(I)=DYYM
  396 CONTINUE
      DYY=YREM
      DO 412 I=NCL,NCR
  412 DYY=AMIN1(DYY,DYYY(I))
      IF(NSS.EQ.0) GO TO 704
      CALL ITERAT(PGRI,MGI,ISAT,MWRZ(NCL,1),HL,HV,PWRI,JS,
     7NC,NCL,3)
      IF(NSS.EQ.1) GO TO 701
      IF(NST.NE.1) GO TO 704
      WRITE(6,713)TIME,JS
  704 CONTINUE
      INX1=1
      INX2=1
      DO 600 I=NCL,NCR
      NXN=NX2Z(I)
      DXN=12.*L(I)/FLOAT(NXN)
      TG2T=0.
      IF(NST.NE.0) GO TO 63
      IF(JS.NE.LSTEP) GO TO 9
   63 IF(I.NE.NCL) GO TO 724
      WRITE(6,20)
   20 FORMAT(3X,5H LUMP,10X,3H H2,14X,3H TF,14X,3H TT,13X,
     74H HG2,14X,3H M2,10X,4H NPH)
  724 CONTINUE
      WRITE(6,725)I
  725 FORMAT(38X,5H*****,16H FLUID PASS NO. ,I5,5H*****)
    9 CONTINUE
      DO 420 JI=1,NXN
      NPH=NPHY(I,JI)
      TG=(TG1(I)+TG2(I,JI,1))/2.
      CGG=FCWV(PGRI,TG)
      X1=2.*MGI*CGG/(HGTY(I,JI)*L(I)*12.)
```

PROGRAM LISTING -- REGEN (Cont'd)

```
      BB=1./X1
      TGN=TG1(I)
      NHB=1
      IF(BB.GT.0.5) NHB=2.5*BB
      BB=BB/FLOAT(NHB)
      FG2G1=(1.-BB)/(1.+BB)
      FG2T=1.-FG2G1
      ADT=FG2T*TT(I,JI,1)
      DO 280 LK=1,NHB
  280 TGN=FG2G1*TGN+ADT
      TG2(I,JI,2)=TGN
      TG2(I,JI,1)=TG2(I,JI,2)
      TG2T=TG2T+TG2(I,JI,2)
      GO TO (397,398,399),NPH
  397 TREF=TSAT
      HFAVG=(HF(I,JI,1)+HF(I,JI+1,1))/2.
      HREF=HL
      CPP=FCHL(TREF)
      TX=TREF
  707 TFX=TREF+(HFAVG-HREF)/CPP
      TX1=(TREF+TFX)/2.
      IF(ABS((TX-TX1)/TX)-.01) 709,709,708
  708 TX=TX1
      CPP=FCHL(TX)
      GO TO 707
  709 FTG=(DYY/2.)*(HGTY(I,JI)/CTT(I))
      FTT=1.-(DYY/CTT(I))*(HTFY(I,JI)+HGTY(I,JI))
      FTF=(DYY/2.)*HTFY(I,JI)/(CTT(I)*CPP)
      FCON=DYY*(HTFY(I,JI)/CTT(I))*(TREF-(HREF/CPP))
      TT(I,JI,2)=FTT*TT(I,JI,1)+FTF*(HF(I,JI,1)+HF(I,JI+1,1))+
     4FTG*(TG1(I)+TG2(I,JI,1))+FCON
      MWRZ(I,JI+1)=MWRZ(I,JI)
      FF2T=DYY*(HTFY(I,JI)/CTFY(I,JI))*CPP
      FF2F1=(DYY/DXN)*(EFY(I,JI)/CTFY(I,JI))*(1.-(HTFY(I,JI)/
     4EFY(I,JI))*(DXN/2.))
      FF2F2=1.-(DYY/CTFY(I,JI))*((HTFY(I,JI)/2.)+(EFY(I,JI)/DXN))
      HF(I,JI+1,2)=FF2F2*HF(I,JI+1,1)+FF2F1*HF(I,JI,1)+
     5FF2T*(TT(I,JI,1)-TREF+(HREF/CPP))
      HFN=HF(I,JI+1,1)
      GO TO 410
  398 WRITE(6,26)
   26 FORMAT(49H CALCULATIONS FOR NPH=2 NOT PERMITTED AT PRESENT.)
      STOP
  399 WRITE(6,27)
   27 FORMAT(49H CALCULATIONS FOR NPH=3 NOT PERMITTED AT PRESENT.)
      STOP
  410 CONTINUE
      TGN=TG2(I,JI,1)
      CALL SUPPT(PGRT,TGN,HFGN,DD,GV,1)
      IF(NST.NE.0) GO TO 21
      IF(JS.NE.LSTEP) GO TO 727
   21 WRITE(6,5032)JI,HFN,TFX,TT(I,JI,1),HFGN,
     7MWRZ(I,JI+1),NPHY(I,JI)
 5032 FORMAT(I6,4X,5E17.5,I6)
 5029 FORMAT(2H  )
      IF(JS.NE.LSTEP) GO TO 727
      WRITE(13,728)HFN,TT(I,JI,1),TG2(I,JI,1),MWRZ(I,JI+1)
  728 FORMAT(4E15.5)
  727 CONTINUE
      IF(NPRINT.NE.0) GO TO 891
      WRITE(6,892)HTFY(I,JI),CTFY(I,JI),EFY(I,JI),HGTY(I,JI)
  892 FORMAT(17H HTF,CTF,EF,HGT   ,4E15.5)
  891 CONTINUE
      IF(JI.NE.NXN) GO TO 420
      IF(I.EQ.NCR) GO TO 420
      MWRZ(I+1,1)=MWRZ(I,NXN+1)
      HF(I+1,1,2)=HF(I,NXN+1,2)
  420 CONTINUE
      TG2AVG(I)=TG2T/FLOAT(NXN)
      CALL SUPPT(PGR,TG1(I),HGIN1(I),DD,DD,1)
      CALL SUPPT(PGR,TG2AVG(I),HGIN2(I),DD,DD,1)
  600 CONTINUE
*     VAPOUR MASS BALANCE
      MI=NC-1
      MGRZ(NCR)=MGI/TUBROW(NCR)
      DO 425 JL=1,MI
      KK=NCR+1-JL
      MGRZ(KK-1)=MGRZ(KK)
  425 CONTINUE
  823 MGF=MGRZ(NCL)
      MGF=MGF*TUBROW(NCL)
      TIME=TIME+DYY
*     RESET
      IF(NST.NE.0) GO TO 22
      IF(JS.NE.LSTEP) GO TO 23
   22 WRITE(6,5029)
   23 CONTINUE
      KK1=NCR-1
      DO 429 I=NCL,KK1
      TG1(I)=TG2AVG(I+1)
      CALL SUPPT(PGRI,TG1(I),HGIN1(I),DD,DD,1)
  429 HGIN2(I+1)=HGIN1(I)
      CALL SUPPT(PGRI,TG2AVG(NCL),HGIN2(NCL),DD,DD,1)
      DO 430 I=NCL,NCR
      NXN=NX2Z(I)
      IF(I.EQ.NCR) GO TO 1031
      HF(I+1,1,2)=HF(I,NXN+1,2)
 1031 IF(I.EQ.NCL) GO TO 1032
      HF(I,1,1)=HF(I,1,2)
 1032 CONTINUE
      MWZ(I,NXN+1)=MWRZ(I,NXN+1)
      DO 430 JJ=1,NXN
      TT(I,JJ,1)=TT(I,JJ,2)
      HF(I,JJ+1,1)=HF(I,JJ+1,2)
      MWZ(I,JJ)=MWRZ(I,JJ)
  430 CONTINUE
      YREM=YREM-DYY
      IF(NST.NE.0) GO TO 71
      IF(JS.NE.LSTEP) GO TO 813
   71 WRITE(6,48)DYY,TG1(NCL),TG1(NCL+1),TG1(NCL+2),TG1(NCL+3)
   48 FORMAT(10H DYY,TG1  ,5F15.5)
      IF(JS.NE.LSTEP) GO TO 813
      WRITE(13,814)TG1(NCL),TG1(NCL+1),TG1(NCL+2),TG1(NCL+3)
  814 FORMAT(4F15.5)
  813 CONTINUE
      IF(JS.NE.LSTEP) GO TO 225
 1000 CONTINUE
*     GAS-SIDE PRESSURE DROP
      WRITE(6,65)
   65 FORMAT(46X,28H ** PRESSURE DROP RESULTS **)
```

```
      WRITE(6,5029)
      WRITE(6,5029)
      WRITE(6,801)
      WRITE(6,803)
 801  FORMAT(12H ** GAS SIDE)
 803  FORMAT(3X,5H PASS,7X,10H MASS FLOW,9X,8H INLET P,10X,
     78H INLET T,10X,7H EXIT T,10X,9H PR. DROP)
      DO 1008 JL=1,NC
      I=NCR+1-JL
      TA1=TG1(I)
      TA2=TG2AVG(I)
      IF(I.NE.NCR) GO TO 1002
      PGR(I)=PGRI
      GO TO 1003
1002  PGR(I)=PGR(I+1)-PDD
1003  CONTINUE
      DIST=L(I)*12./TUBROW(I)
      CALL PDROPR(PGR(I),TA1,TA2,MGRZ(I),DHO(I),DO(I),ACO(I),DIST,
     7RM(I),BT(I),PDD)
      WRITE(6,805)I,MGRZ(I),PGR(I),TA1,TA2,PDD
 805  FORMAT(I6,4X,5F17.5)
1008  CONTINUE
      PGRE=PGR(NCL)-PDD
      WRITE(6,858)PGRE,HGIN2(NCL)
 858  FORMAT(25H EXIT PRESSURE, ENTH     ,2E15.5)
      WRITE(6,5029)
      WRITE(6,5029)
*     FLUID PRESSURE DROP
      WRITE(6,856)
 856  FORMAT(14H ** FLUID SIDE)
      WRITE(6,857)
 857  FORMAT(3X,5H PASS,9X,5H FLOW,14X,4H NPH,12X,7H LENGTH,9X,
     711H INLET PRES,8X,9H PR. DROP)
      PWRX=PWR
      J1=1
      DO 1030 I=NCL,NCR
      J1E=NX2Z(I)-(J2E(I)+J3E(I))
      LZ=VAPL1(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1013
      MWR=MWRZ(I,1)
1012  CALL SATP(PWRX,TWV,DD,DD,HL,HV,1)
      J2=J1E+J1
      HFA=(HF(I,1,1)+HF(I,J2,1))/2.
      TX=TWV
1019  CW=FCWL(TX)
      TW=TWV+(HFA-HL)/CW
      TX1=.5*(TWV+TW)
      IF(ABS(TX-TX1)/TX-.01) 1017,1017,1018
1018  TX=TX1
      GO TO 1019
1017  CONTINUE
      CALL PDROP1(PWRX,TW,MWR,DHI(I),ACI(I),LZ,1,PDD,DD,DD,DD)
      NPH=1
      WRITE(6,859)I,MWR,NPH,LZ,PWRX,PDD
 859  FORMAT(I6,4X,E17.5,I9,8X,3E17.5)
      PWRX=PWRX-PDD
1013  LZ=VAPL2(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1016
      J1=J1E+1
      J2=J2E(I)+J1
```

PROGRAM LISTING -- REGEN (Cont'd)

```
      MWR=(MWRZ(I,J1)+MWRZ(I,J2))/2.
      CALL SATP(PWRX,TWR,DD,DD,HL,HV,1)
      XENT=(HF(I,J1,1)-HL)/(HV-HL)
      XEXT=(HF(I,J2,1)-HL)/(HV-HL)
      IF(XENT.LT.0.) XENT=0.
      IF(XEXT.GT.1.) XEXT=1.
      CALL PDROP2(PWRX,TWR,XENT,XEXT,PWR,DHI(I),ACI(I),LZ,PDD)
      NPH=2
      WRITE(6,859)I,MWR,NPH,LZ,PWRX,PDD
      PWRX=PWRX-PDD
 1016 LZ=VAPL3(I)/(12.*ACI(I))
      IF(LZ.EQ.0.) GO TO 1030
      J1=J2E(I)+J1E+1
      J2=J3E(I)+J1
      HFA=(HF(I,J1,1)+HF(I,J2,1))/2.
      MWR=(MWRZ(I,J1)+MWRZ(I,J2))/2.
      CALL SUPPI(PWRX,TWR,HFA,DD,DD,3)
      CALL PDROP1(PWRX,TWR,MWR,DHI(I),ACI(I),LZ,3,PDD,DD,DD,DD)
      NPH=3
      WRITE(6,859)I,MWR,NPH,LZ,PWRX,PDD
      WRITE(6,5029)
      PWRX=PWRX-PDD
 1030 CONTINUE
      PWRE=PWRX
      NX2=NX2Z(NCR)
      WRITE(6,861)PWRE,HF(NCR,NX2+1,1)
  861 FORMAT(25H EXIT PRESSURE, ENTH      ,2E15.5)
      RETURN
      END
```

SUBROUTINE RGEOMC

RGEOMC calculates all geometric constants for REGEN.

NOMENCLATURE -- RGEOMC

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of RGEOMC are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
NC	Fluid pass number	--

PROGRAM LISTING -- RGEOMC

```
      SUBROUTINE RGEOMC(NC)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NRENDA
      COMMON NRENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTI(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2F(10),J3F(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NNG,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
*     HYDRAULIC DIAMETERS
*     USE FUNCTIONS
      VOLB=(3.1416/4.)*(DO(NC)**2-DI(NC)**2)
      A1=1.-RM(NC)
      A2=X2L(NC)-DO(NC)
      BH(NC)=A2
      ACO(NC)=A2*RM(NC)
      DHO(NC)=4.*RM(NC)*DS(NC)/(6.*A1)
      VOLO=A1*A2*WT(NC)
      ACI(NC)=(3.1416/4.)*(DI(NC)**2)
      DHI(NC)=DI(NC)
*     TUBE METAL PROPERITIES ARE ASSUMED CONSTANT IN THIS PROGRAM
*     ARRANGEMENT
      MI=NM(NC)
      TX=0.
      GO TO (140,145),MI
*     NOTE THAT A1 PRESENTLY FORMULATED THE FUNCTIONS FCMS(TX),
*     FRMS(TX),FCMC(TX),FRMC(TX). THEY DO NOT DEPEND ON TEMPERATURE
*     WHICH IS NOT DEFINED AT THIS POINT. (SUITABLE TEMPERATURES
*     COULD BE DEFINED FOR THIS PURPOSE)
 140  CTB=FCMS(TX)
      RTB=FRMS(TX)
      GO TO 150
 145  CTB=FCMC(TX)
      RTB=FRMC(TX)
 150  MI=NMO(NC)
      GO TO(155,160),MI
 155  CTO=FCMS(TX)
```

PROGRAM LISTING -- RGEOMC (Cont'd)

```
      RTO=FRMS(IX)
      GO TO 180
160   CTO=FCMC(IX)
      RTO=FRMC(IX)
180   CTT(NC)=VOLB*CTH*RTH
      VOL(NC)=X2L(NC)*X2T(NC)-(3.1416/4.)*DO(NC)**2-VOLO
      IF(NSU(NC).NE.1) CTT(NC)=CTT(NC)+VOLO*CTO*RTO
      CTT(NC)=CTT(NC)/1728.
      RETURN
      END
```

SUBROUTINE STEPSR

STEPSR calculates the stability limits on lump size for each lump of REGEN. It employs the subroutines HT1PB, HT2PB, HTWTM, PHASE, and SUPPT.

NOMENCLATURE -- STEPSR

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of STEPSR are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
HW	Enthalpy of working fluid	Btu/lb
MGR	Mass flow rate of gas	lb/sec
MWR	Mass flow rate of working fluid	lb/sec
NC	Fluid pass number	--
NX2	Number of lumps for a given coil	--
PG	Pressure of gas	lb/in.^{2}
PW	Pressure of working fluid	lb/in.^{2}
TG	Bulk gas temperature	°F
TI	Wall temperature at mid-node of a lump	°F
TW	Bulk fluid temperature	°F
X	Quality of bulk mass within a lump	--
X2G	Geometric limit on lump size	in.

PROGRAM LISTING -- STEPSR

```
      SUBROUTINE STEPSR(PW,TW,HW,PG,TG,TI,MWR,MGR,X,NC,X2G,NX2)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MWR,MGR
*     PW,HW,PG,TG,MWR,MGR,NC,X2G ARE INPUT
*     NX2,X,TW,HG ARE RETURNED.
      CALL PHASE(PW,TW,HW,X,GVL,GVV,HL,HV)
*     GAS PROPERTIES
      CALL SUPPT(PG,TG,HG,S,GV,1)
      CG=FCWV(PG,TG)
      RG=1./GV
*     OBTAIN HEAT TRANS COEFFS; HTGT,HTTF
*     OBTAINING HTGT
      G=MGR/ACO(NC)
      CALL HTWTM(HTGT,NC,G,TG,PG)
*     OBTAINING HTTF
      GF=ABS(MWR/ACI(NC))
      GO TO (60,70,60),NPH
  60  CALL HT1PB(HTTF,NC,GF,PW,TW)
      GO TO 100
  70  CALL HT2PB(HTTF,NC,GF,TW,TI,X,PW,GVL,GVV,HL,HV)
 100  CONTINUE
*     COMPUTE THT PARAMETERS
      EG=ABS(MGR*12.*L(NC))*CG/FLOAT(NX2)
      EF=ABS(MWR*CW)
      HGT=HTGT*3.14159*DO(NC)
      HTF=HTTF*3.14159*DI(NC)
      CTF=RW*ACI(NC)*CW/1728.
*     STEP SIZE CALCULATION
      X2=2.*EF/HTF
      DX2=AMIN1(X2*FRAC,X2G)
```

PROGRAM LISTING -- STEPSR (Cont'd)

```
      NX2=INTSTE(DX2,X2G)                                               01010
      IF(NPH.EQ.2) NX2=5                                                01020
      IF(NX2.GT.1) DX2=X2G/FLOAT(NX2)                                   01030
      RETURN                                                            01100
      END                                                               01110
```

SUBROUTINE PDROPR

PDROPR calculates the vapor-side pressure drop for a ball-matrix regenerator surface. It employs the subroutine SUPPT.

NOMENCLATURE -- PDROPR

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of PDROPR are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
ACOL	Flow cross-section area per unit length	in.
BTH	Ball-matrix thickness in flow direction	in.
D	Tube diameter, outside	in.
DH	Hydraulic flow diameter	in.
DP	Vapor pressure drop	lb/in.^{2}
L	Tube length	in.
P1	Inlet vapor pressure	lb/in.^{2}
RM	Porosity of ball-matrix	--
T1	Inlet vapor temperature	°F
T2	Exit vapor temperature	°F
W	Mass flow rate of vapor	lb/sec

PROGRAM LISTING -- PDROPR

```
      SUBROUTINE PDROPR(P1,T1,T2,W,DH,D,ACOL,L,RM,BTH,DP)
      REAL L
      GC=32.17
      T=(T1+T2)/2.
      AC=ACOL*L
      G=W/AC
      V=FVWV(T)
      CALL SUPPT(P1,T1,H1,S,GV1,1)
      CALL SUPPT(P1,T2,H1,S,GV2,1)
      RO1=1./GV1
      RO2=1./GV2
      REY=ABS((12.*3600.)*(G*DH/V))
      SIG=RM
      SA=4.*BTH/DH
      X=ALOG(REY/1000.)
      F=EXP(-.6539+X*(-.173429+X*(.046373-.007571*X)))
      PREF=(144./GC)*(G*G/(2.*RO1))
      AR1=1.+(SIG**2)
      AR2=(RO1/RO2)-1.
      AR3=F*SA*(RO1+RO2)/(RO2*2.)
      DP=PREF*(AR1+AR2+AR3)
      RETURN
      END
```

SUBROUTINE HTWTM

HTWTM calculates the heat transfer coefficient between gas (or superheat vapor) and ball-matrix outer tube surface.

NOMENCLATURE -- HTWTM

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of HTWTM are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
G	Mass velocity of gas	lb/in.^{2} sec
HTC	Heat transfer coefficient	Btu/sec in.^{2} °F
NC	Fluid pass number	--
PPG	Gas pressure	lb/in.^{2}
TEMP	Bulk gas temperature	°F

PROGRAM LISTING -- HTWTM

```
      SUBROUTINE HTWTM(HTC,NC,G,TEMP,PPG)
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HIIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),FG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGT,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TI(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL KG
      KG=FKWV(TEMP)
      VISG=FVWV(TEMP)
      CPG=FCWV(PPG,TEMP)
      NOTE 43200=12*3600
      REG=43200.*G*DHO(NC)/VISG
      PRG=VISG*CPG/KG
      HBTO=.230*REG**(-.3)*PRG**(-.667)*G*CPG
      BM=SQRT(3600.*12.*HBTO/(FKM(TEMP)*DS(NC)))
      Z=3.63*BH(NC)*BM
      EM=TANH(Z)/Z
      SMTSBT=18.8*BH(NC)*BT(NC)/DO(NC)
      HTC=EM*SMTSBT*HBTO
      RETURN
      END
```

Section 9

COMBUSTOR MODEL

Section 9

COMBUSTOR MODEL

MAIN PROGRAM – COMBST

The main program for the combustor model is entitled COMBST. This model uses the subroutines COMB1, COMB2, and COMB3.

COMBST links together the flame temperature, thermal transient, and emission submodels. It is, at present, set up to derive the steady-state solution through an iteration on the value of TA. The accuracy of convergence has been set as 5%, and must be changed by internal program modification if tighter accuracy is desired.

NOMENCLATURE -- COMBST

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of COMBST are in the COMMON of MAINSYS.

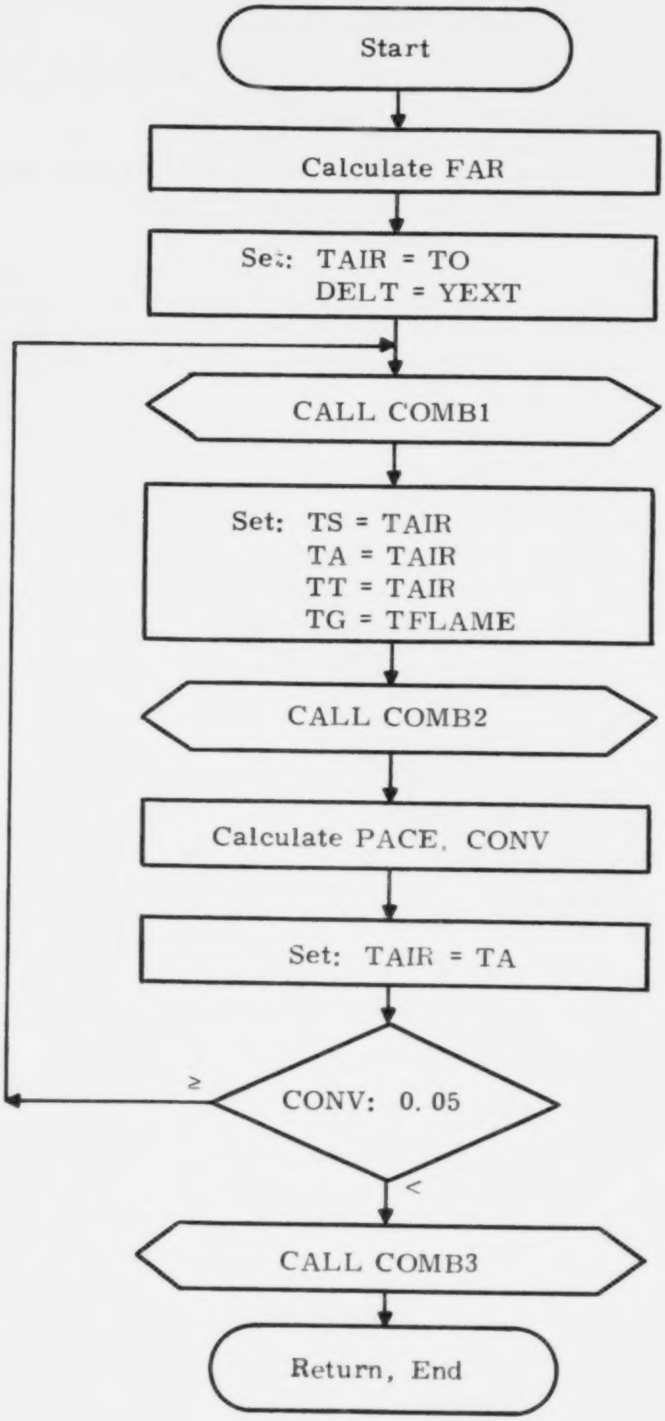
FORTRAN Variables in Argument list:

FORTRAN Variable	Definition	Units
CP	Moles of unburned carbon in products	moles
PACE	Pressure of gas at combustor exhaust	lb/in^2
PACI	Pressure of air at combustor inlet	lb/in^2
TA	Temperature of air	°F
TFLAME	Temperature of flame	°F
TG	Temperature of gas	°F
TS	Temperature of shell	°F
TT	Temperature of tube	°F

Other Selected Fortran Variables:

FORTRAN Variable	Definition	Units
CONV	Convergence limit	--
DELT	External time step	sec
FAR	Fuel/air ratio	--

FLOW DIAGRAM -- COMBST


Start
Calculate FAR
Set: TAIR = TO
DELT = YEXT
CALL COMB1
Set: TS = TAIR
TA = TAIR
TT = TAIR
TG = TFLAME
CALL COMB2
Calculate PACE, CONV
Set: TAIR = TA
≥
CONV: 0. 05
<
CALL COMB3
Return, End

PROGRAM LISTING -- COMBST

```
      SUBROUTINE COMBST(PACI,PACE,TG,TS,TA,TT,CP,TFLAME)
      COMMON AP,B,CH,CHR,CO,CO2P
      COMMON CO2S,DCS,DCT,DTH,EQUIV,F
      COMMON FS,H2OP,H2OS,HP,HR,HTFLAM
      COMMON HTIN,LHV,LHVT,LCS,LCT,MAIR
      COMMON MFLUID,MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R,O2S
      COMMON PO,SP1,SSA,STA,STG,TO
      COMMON WS,WT,YEXT,DD1,DD2,DD3
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MPUMP
      FAR=MFUEL/MAIR
      TAIR=TO
      DELT=YEXT
   10 CALL COMB1(TAIR,TFLAME,CP)
      TS=TAIR
      TA=TAIR
      TT=TAIR
      TG=TFLAMF
      CALL COMB2(TS,TA,TT,TFLAME,TG,DELT,DPT)
      PACE=PACI-DPT
      CONV=ABS((TA-TAIR)/TAIR)
      TAIR=TA
      IF(CONV-0.05) 15,10,10
   15 CALL COMB3(TAIR,CP,DELT)
      RETURN
      END
```

SUBROUTINE COMB1

The submodel COMB1 calculates the combustion flame temperature. It employs the subroutine ENERGY.

The variables which specify the fuel have been set internally as:

C = 0.85
H = 0.15
FMAX = 0.1
FMIN = 0.01

NOMENCLATURE -- COMB1

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of COMB1 are in the COMMON of MAINSYS.

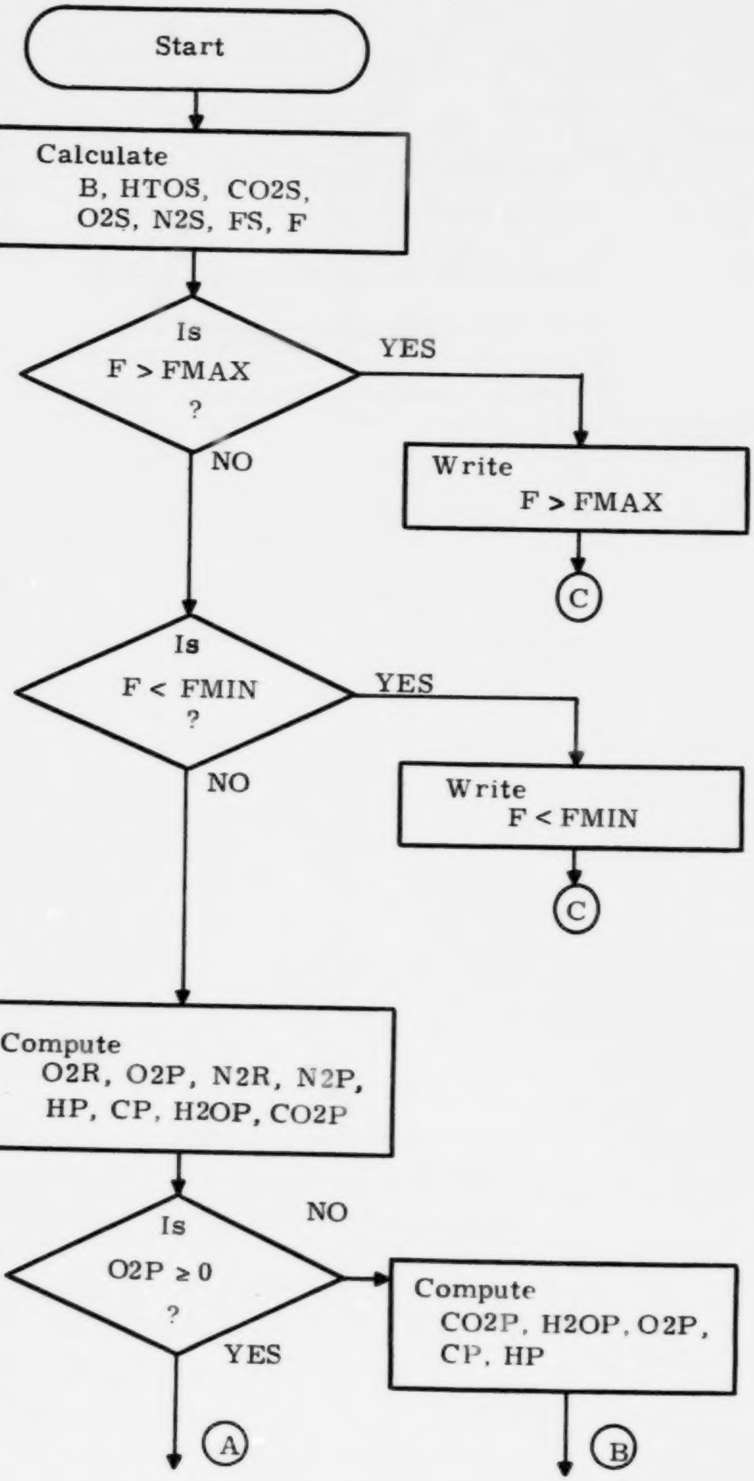
FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
CP	Moles of unburned carbon in products	moles
TAIR	Air temperature	°F
TFLAME	Flame temperature	°F

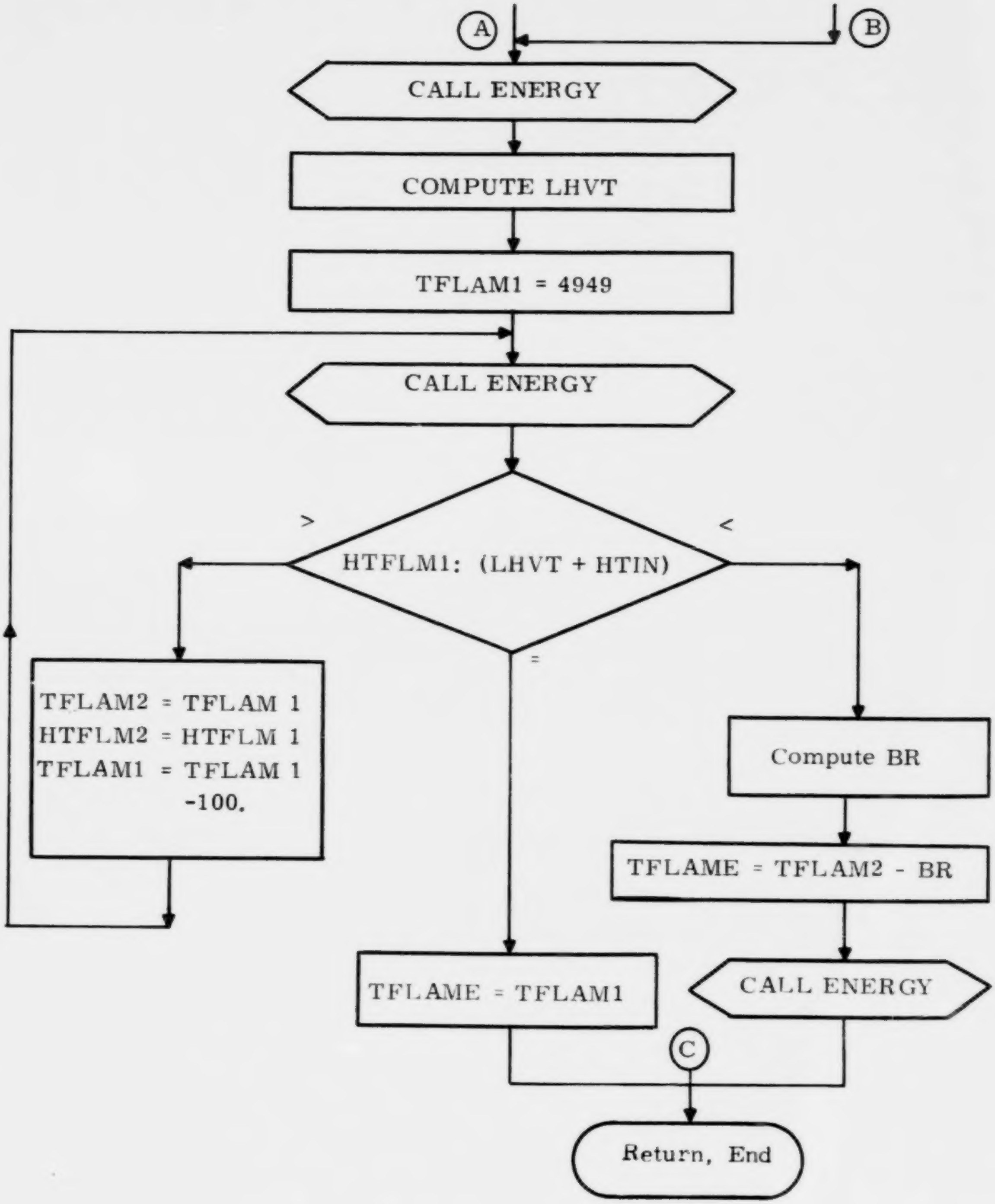
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
FMAX	Fuel air ratio, maximum limit	--
FMIN	Fuel air ratio, minimum limit	--

FLOW DIAGRAM -- COMB1


Start
Calculate B, HTOS, CO2S, O2S, N2S, FS, F
Is F > FMAX ?
YES
NO
Write F > FMAX
C
Is F < FMIN ?
YES
NO
Write F < FMIN
C
Compute O2R, O2P, N2R, N2P, HP, CP, H2OP, CO2P
Is O2P ≥ 0 ?
NO
YES
Compute CO2P, H2OP, O2P, CP, HP
A
B

FLOW DIAGRAM -- COMB1 (Cont'd)



A
B
CALL ENERGY
COMPUTE LHVT
TFLAM1 = 4949
CALL ENERGY
>
<
HTFLM1: (LHVT + HTIN)
=
TFLAM2 = TFLAM 1
HTFLM2 = HTFLM 1
TFLAM1 = TFLAM 1 -100.
Compute BR
TFLAME = TFLAM2 - BR
CALL ENERGY
TFLAME = TFLAM1
C
Return, End

PROGRAM LISTING -- COMB1

```
      SUBROUTINE COMB1(TAIR,TFLAME,CP)
      COMMON AP,B,CH,CHR,CO,CO2P
      COMMON CO2S,DCS,DCT,DTH,EQUIV,F
      COMMON FS,H2OP,H2OS,HP,HR,HTFLAM
      COMMON HTIN,LHV,LHVT,LCS,LCT,MAIR
      COMMON MFLUID,MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R,O2S
      COMMON PO,SP1,SSA,STA,STG,TO
      COMMON WS,WT,YEXT,DD1,DD2,DD3
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MOLAIR
*     FOR ANY HYDROCARBON FUEL AIR MIXTURE
*     C PERCENT CARBON BY WEIGHT, H PERCENT HYDROGEN BY WEIGHT
*     LHV LOWER HEATING VALVE; COMBUSTION LIMITS  FMAX,FMIN
*     CALCULATION OF FLAME TEMPERATURE
*                             --BOILER INLET
*     FOR KEROSENE
      FMAX=.1
      FMIN=.01
      C=.85
      H=.15
      B=12.*(H/C)
      CHR=B+12.
*     STOCHIOMETRY
      H2OS=B/2.
      CO2S=1.
      O2S=CO2S+H2OS/2.
      N2S=4.*O2S
      FS=(12.+B)/(32.*O2S+28.*N2S)
*     OFF STOCHIOMETRIC CONDITIONS
      F=MFUEL/MAIR
      IF(F.GT.FMAX) GO TO 100
      IF(F.LT.FMIN) GO TO 200
      EQUIV=F/FS
      MOLAIR=1./EQUIV
      O2R=MOLAIR*O2S
      O2P=O2R-O2S
      N2R=MOLAIR*N2S
      N2P=N2R
      HP=0.
      CP=0.
      H2OP=H2OS
      CO2P=CO2S
      IF(O2P.GE.0.) GO TO 40
      CO2P=CO2S-(O2S-O2R)/2.
      H2OP=H2OS-(O2S-O2R)
      O2P=0.
      CP=1.-CO2P
      HP=B-2.*H2OP
   40 CONTINUE
*     FLAME TEMPERATURE CALCULATION
      CALL ENERGY(TAIR,HTIN,H2OP,CO2P,N2P,O2P)
      LHVT=(12.+B)*LHV
      TFLAM1=4949.
   50 CONTINUE
      CALL ENERGY(TFLAM1,HTFLM1,H2OP,CO2P,N2P,O2P)
      IF(HTFLM1-(LHVT+HTIN)) 70,350,80
   70 BR=(HTFLM2-(LHVT+HTIN))/(HTFLM2-HTFLM1)*100.
      TFLAME=TFLAM2-BR
      CALL ENERGY(TFLAME,HTFLAM,H2OP,CO2P,N2P,O2P)
```

PROGRAM LISTING -- COMB1 (Cont'd)

```
      GO TO 400
 80   TFLAM2=TFLAM1
      HTFLM2=HTFLM1
      TFLAM1=TFLAM1-100.
      GO TO 50
350   TFLAME=TFLAM1
      GO TO 400
100   WRITE(6,110)
110   FORMAT(7H F>FMAX)
      GO TO 300
200   WRITE(6,120)
120   FORMAT(7H F<FMIN)
300   TFLAME=0.
400   RETURN
      END
```

SUBROUTINE COMB2

The submodel COMB2 calculates the combustor thermal transients. It employs the following subroutines:

TRHT
PDROP1
FCMS
FCA
FVA
FKA
FDA
FCG
FVG
FKG
FDG

NOMENCLATURE -- COMB2

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of COMB2 are in the COMMON of MAINSYS.

FORTRAN Variables in Argument List:

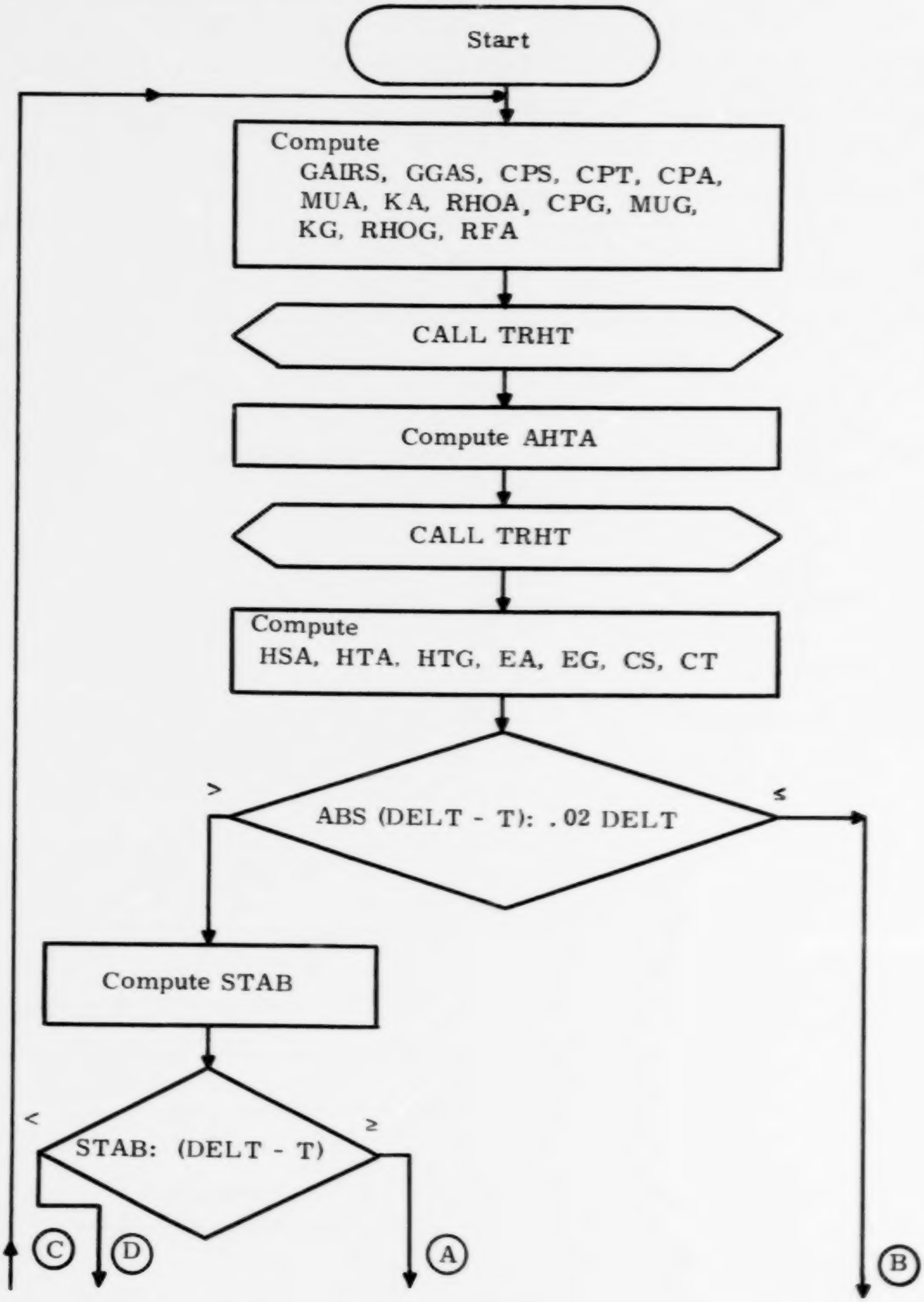
FORTRAN Variable	Definition	Units
DELT	External time step	sec
DPT	Pressure drop across combustor	lb/in^2
TA	Temperature of air	°F
TF	Temperature of flame	°F
TG	Temperature of gas	°F
TS	Temperature of shell	°F
TT	Temperature of tube	°F

Other Selected FORTRAN Variables:

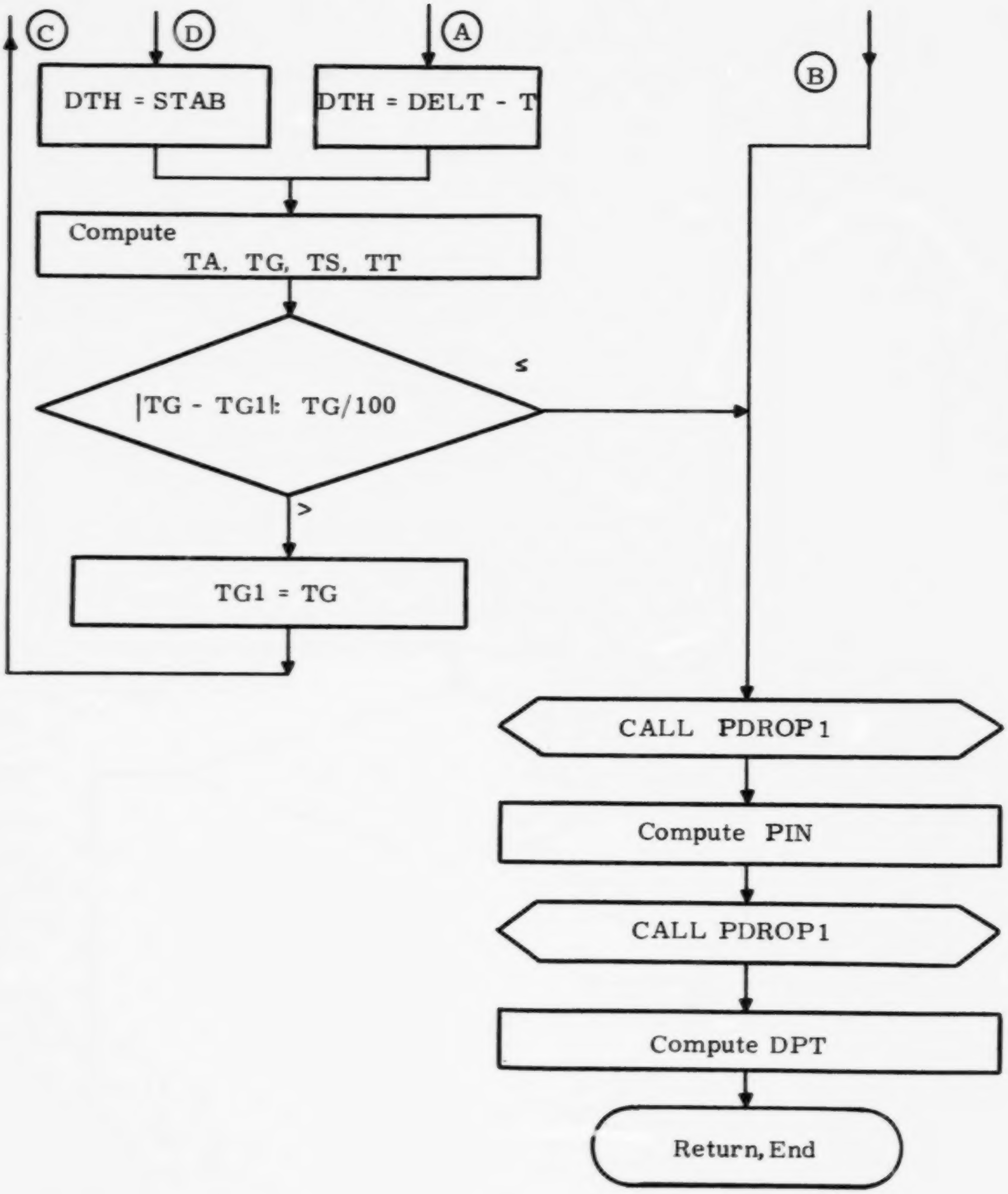
FORTRAN Variable	Definition	Units
AHSA	Heat transfer coefficient between shell and air	Btu/sec °F
AHTA	Heat transfer coefficient between tube and air	Btu/sec °F
AHTG	Heat transfer coefficient between tube and gas	Btu/sec °F
CPA	Specific heat of air	Btu/lb °F
CPS	Specific heat of shell	Btu/lb °F
CPT	Specific heat of tube	Btu/lb °F
GAIRS	Air flow rate	lb/sec in^2

FORTRAN Variable	Definition	Units
GGAS	Gas flow rate	lb/sec in^2
STAB	Stability time step	sec
WS	Shell weight	lb
WT	Tube weight	lb

FLOW DIAGRAM -- COMB2


Start
Compute
GAIRS, GGAS, CPS, CPT, CPA, MUA, KA, RHOA, CPG, MUG, KG, RHOG, RFA
CALL TRHT
Compute AHTA
CALL TRHT
Compute
HSA, HTA, HTG, EA, EG, CS, CT
ABS (DELT - T): .02 DELT
>
≤
Compute STAB
STAB: (DELT - T)
<
≥
C
D
A
B

FLOW DIAGRAM -- COMB2 (Cont'd)



C
D
A
B
DTH = STAB
DTH = DELT - T
Compute TA, TG, TS, TT
|TG - TG1|: TG/100
≤
>
TG1 = TG
CALL PDROP1
Compute PIN
CALL PDROP1
Compute DPT
Return, End

PROGRAM LISTING -- COMB2

```
      SUBROUTINE COMB2(TS,TA,TT,TF,TG,DELT,DPT)
*     CALCULATION OF AIR PREHEAT AND COMBUSTION GAS COOLING
*     LOSSES IN COMBUSTOR
      COMMON AP,B,CH,CHR,CO,CO2P
      COMMON CO2S,DCS,DCT,DTH,EQUIV,F
      COMMON FS,H2OP,H2OS,HP,HR,HTFLAM
      COMMON HTIN,LHV,LHVT,LCS,LCT,MAIR
      COMMON MFLUID,MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R,O2S
      COMMON PO,SP1,SSA,STA,STG,TO
      COMMON WS,WT,YEXT,DD1,DD2,DD3
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL KA,KG,MGAS,MUA,MUG
      T=0.
      ACS=(DCS*(SSA+STA)/(4.*LCS))/12.
      ACT=(DCT*(STG)/(4.*LCT))/12.
      MGAS=MAIR+MFUEL
      GAIRS=MAIR/ACS
      GGAS=MGAS/ACT
      RFA=MFUEL/MAIR
      TG1=TG
 200  CONTINUE
      CPS=FCMS(TS)
      CPT=FCMS(TT)
      CPA=FCA(TA)
      MUA=FVA(TA)
      KA=FKA(TA)
      RHOA=1./FDA(TA)
      CPG=FCG(TG,RFA)
      MUG=FVG(TG)
      KG=FKG(TG)
      RHOG=1./FDG(TG,RFA)
      CALL TRHT(GAIRS,DCS,MUA,CPA,KA,AHSA)
      AHTA=AHSA
      CALL TRHT(GGAS,DCT,MUG,CPG,KG,AHTG)
      HSA=AHSA*SSA
      HTA=AHTA*STA
      HTG=AHTG*STG
      EA=MAIR*CPA
      EG=(MAIR+MFUEL)*CPG
      CS=WS*CPS
      CT=WT*CPT
      IF(ABS(DELT-T)-.02*DELT) 600,600,700
 700  STAB=AMIN1(CS/HSA,CT/(HTA+HTG))
      IF(STAB-(DELT-T)) 400,300,300
 300  DTH=DELT-T
      GO TO 500
 400  DTH=STAB
 500  CONTINUE
      T=T+DTH
      FAS=HSA/(EA+HSA+HTA)
      FAT=HTA/(EA+HSA+HTA)
      FAO=EA/(EA+HSA+HTA)
      TA=FAS*TS+FAT*TT+FAO*TO
      FGT=HTG/(EG+HTG)
      FGF=EG/(EG+HTG)
      TG=FGT*TT+FGF*TF
      FSA=(HSA*DTH)/CS
      FSS=1.-(HSA*DTH)/CS
```

PROGRAM LISTING -- COMB2 (Cont'd)

```
      TS=FSA*TA+FSS*TS
      FTA=HTA*DTH/CT
      FTG=HTG*DTH/CT
      FTT=1.-(HTA+HTG)*DTH/CT
      TT=FTA*TA+FTG*TG+FTT*TT
      IF(ABS(TG-TG1)-TG/100.) 600,600,900
 900  TG1=TG
      GO TO 200
 600  CONTINUE
      CALL PDROP1(PO,TA,MAIR,DCS,ACS,LCS,4,DPA,0,NBENDA,DPBA)
      PIN=PO-DPA-DPBA
      CALL PDROP1(PIN,TG,MGAS,DCT,ACT,LCT,4,DPG,RFA,NBENDG,DPBG)
      DPT=DPA+DPBA+DPG+DPBG
      RETURN
      END
```

SUBROUTINE COMB3

The submodel COMB3 calculates the combustor emissions.

NOMENCLATURE -- COMB3

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of COMB3 are in the COMMON of MAINSYS.

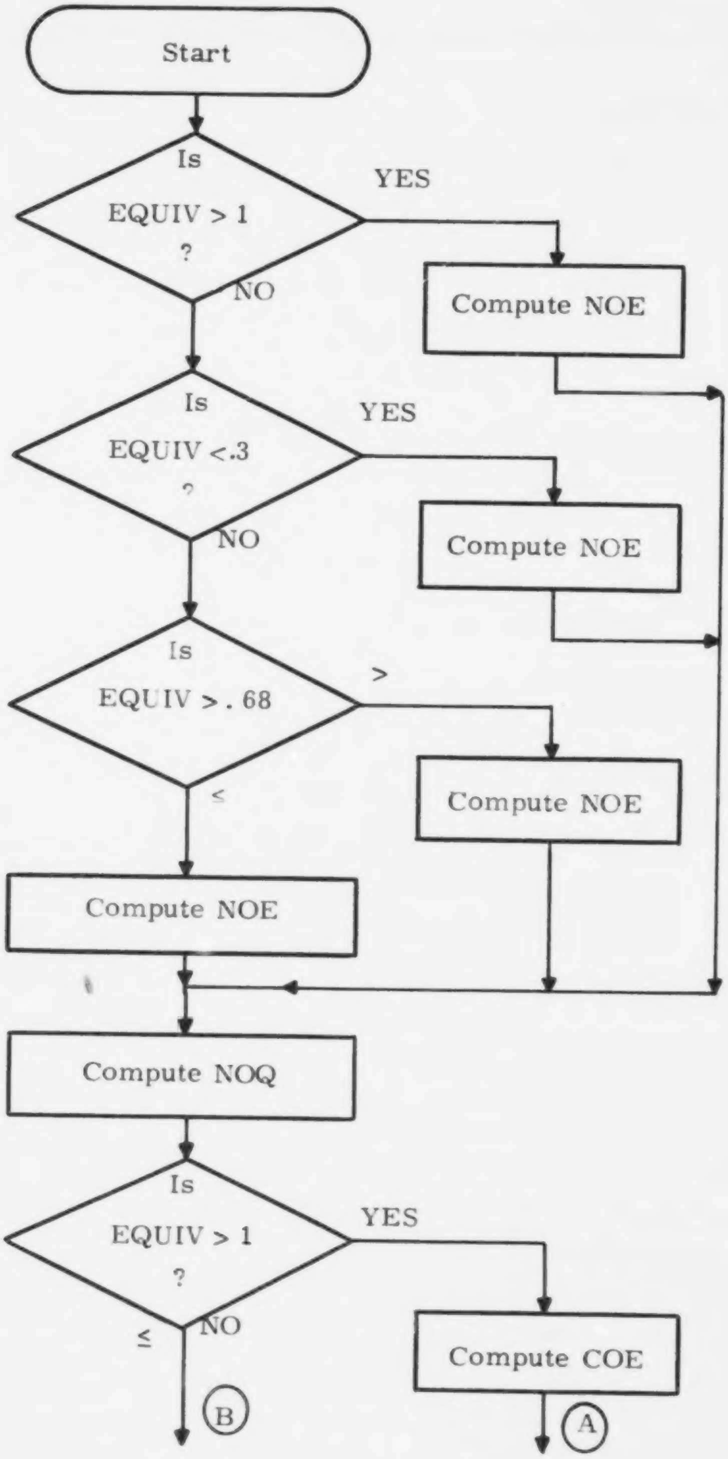
FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
CHP	Moles of unburned carbon in products	moles
DELT	Elapsed time	sec
TAIR	Temperature of air	° F

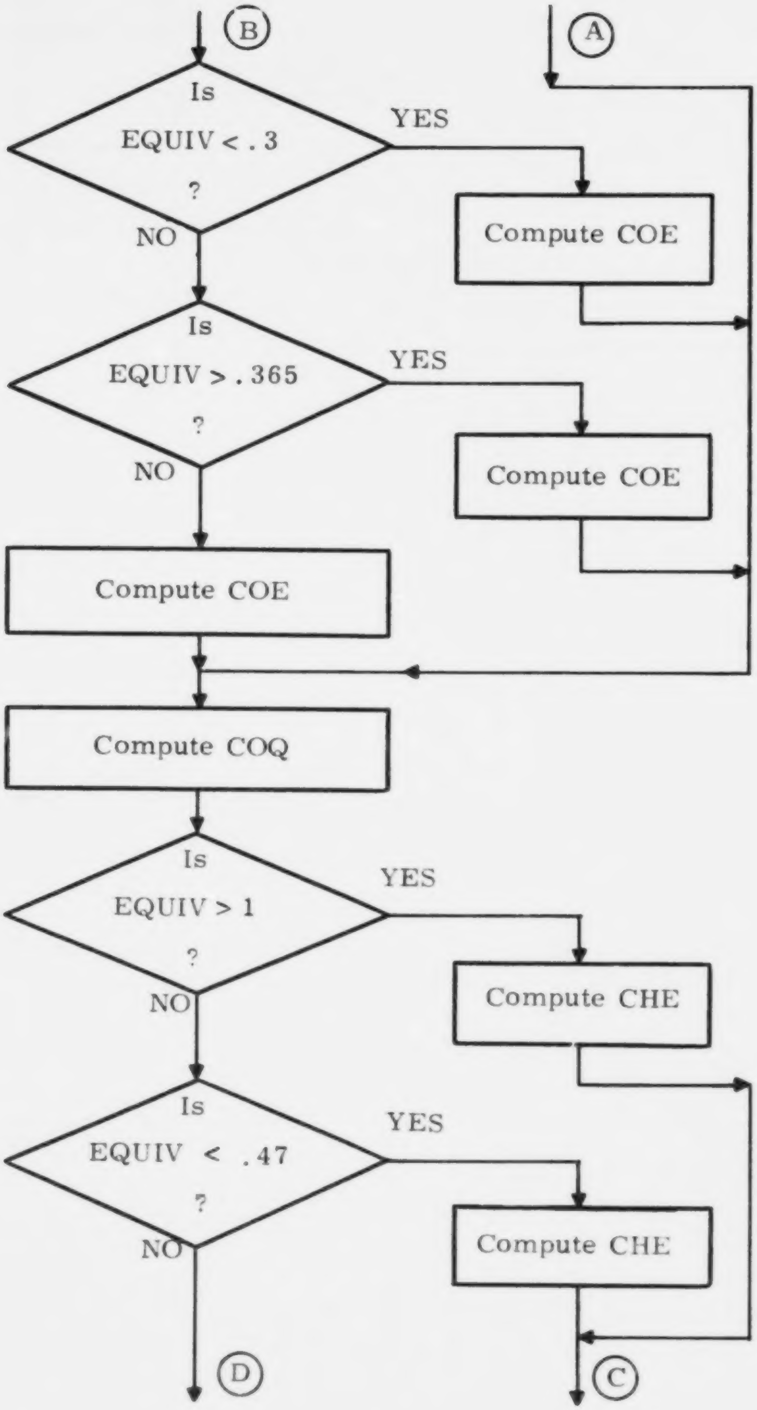
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
CHTOT	Unburned hydrocarbons emitted in time interval DELT	grams/sec
COTOT	Carbon monoxide emitted in time interval DELT	grams/sec
NOTOT	Nitrogen oxide emissions emitted in time interval DELT	grams/sec

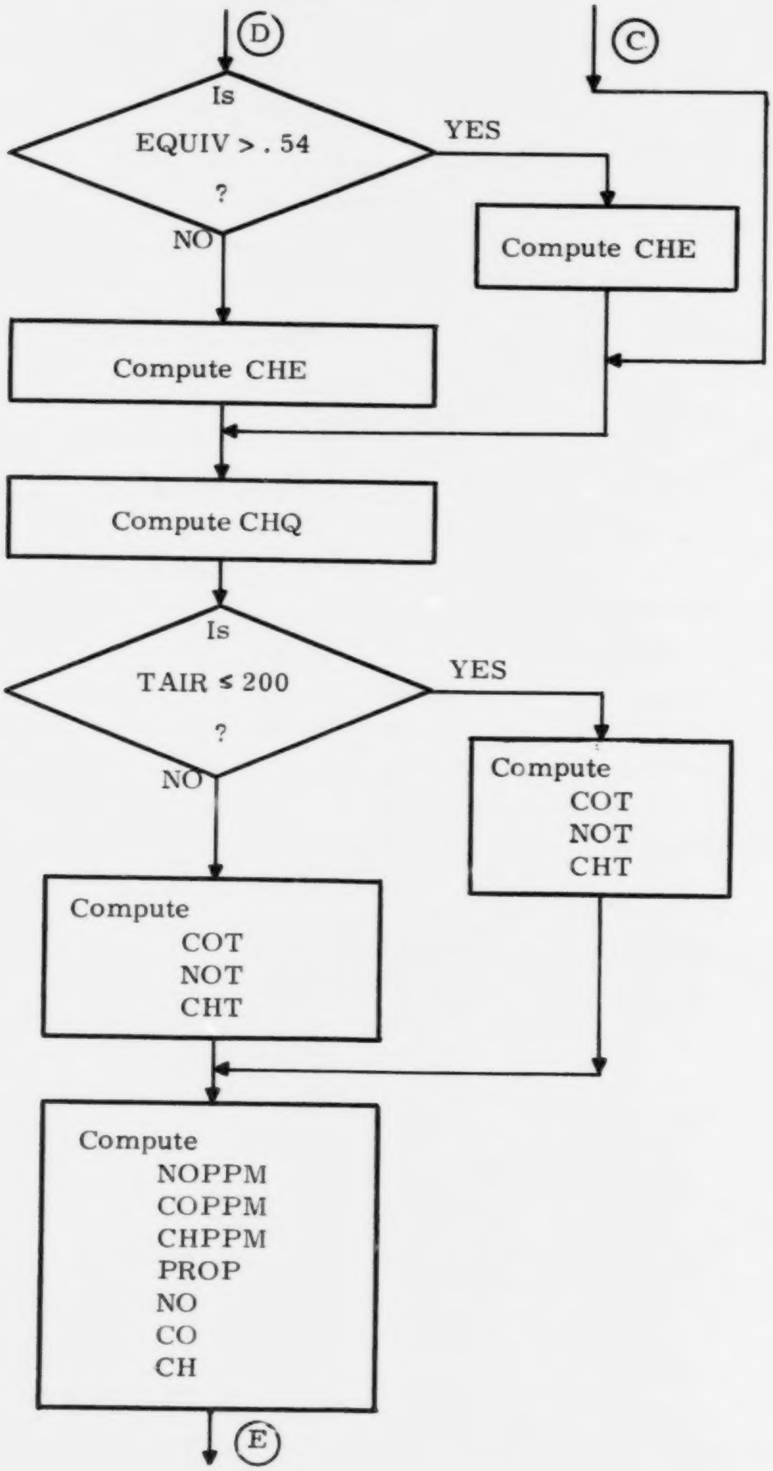
FLOW DIAGRAM -- COMB3


Start
Is EQUIV > 1 ?
YES
NO
Compute NOE
Is EQUIV <.3 ?
YES
NO
Compute NOE
Is EQUIV >. 68
>
≤
Compute NOE
Compute NOE
Compute NOQ
Is EQUIV > 1 ?
YES
≤
NO
Compute COE
B
A

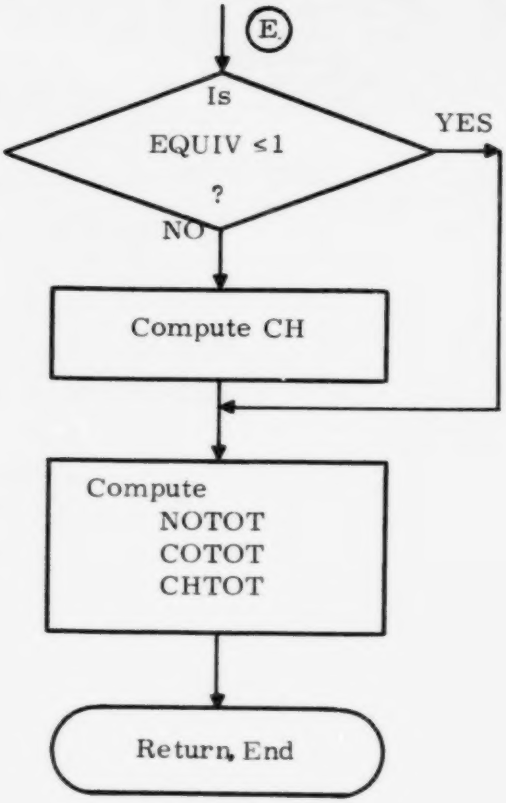
FLOW DIAGRAM -- COMB3 (Cont'd)


B
A
Is
EQUIV < .3
?
YES
NO
Compute COE
Is
EQUIV > .365
?
YES
NO
Compute COE
Compute COE
Compute COQ
Is
EQUIV > 1
?
YES
NO
Compute CHE
Is
EQUIV < .47
?
YES
NO
Compute CHE
D
C

FLOW DIAGRAM -- COMB3 (Cont'd)


D
C
Is
EQUIV > . 54
?
YES
NO
Compute CHE
Compute CHE
Compute CHQ
Is
TAIR ≤ 200
?
YES
NO
Compute
COT
NOT
CHT
Compute
COT
NOT
CHT
Compute
NOPPM
COPPM
CHPPM
PROP
NO
CO
CH
E

FLOW DIAGRAM -- COMB3 (Cont'd)


E
Is
EQUIV ≤1
?
YES
NO
Compute CH
Compute
NOTOT
COTOT
CHTOT
Return, End

PROGRAM LISTING -- COMB3

```
      SUBROUTINE COMB3(TAIR,CHP,DELT)
      COMMON AP,B,CH,CHR,CO,CO2P
      COMMON CO2S,DCS,DCT,DTH,EQUIV,F
      COMMON FS,H2OP,H2OS,HP,HR,HTFLAM
      COMMON HTIN,LHV,LHVT,LCS,LCT,MAIR
      COMMON MFLUID,MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NO,NP,O2P,O2R,O2S
      COMMON PO,SP1,SSA,STA,STG,TO
      COMMON WS,WT,YEXT,DD1,DD2,DD3
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MF,NOE,NOPPM,NOQ,NOT,NOTOT
*     CALCULATION OF POLLUTANTS FORMED IN TIME DELT
      MF=MFUEL
      IF(EQUIV.GT.1.) GO TO 20
      IF(EQUIV.LT.0.3) GO TO 30
      IF(EQUIV.GT.0.68) GO TO 10
      NOE=2.951E+2+EQUIV*(-1.533E+3+2.055E+3*EQUIV)
      GO TO 40
   10 NOE=1.899E+3+EQUIV*(-7.200E+3+6.915E+3*EQUIV)
      GO TO 40
   20 NOE=1613.
      GO TO 40
   30 NOE=10.
   40 CONTINUE
      NOQ=NOE*HR
      IF(EQUIV.GT.1.) GO TO 60
      IF(EQUIV.LT.0.3) GO TO 70
      IF(EQUIV.GT.0.365) GO TO 50
      COE=-3466.*EQUIV+1485.
      GO TO 80
   50 COE=1.808E+3+EQUIV*(-6.662E+3+6.480E+3*EQUIV)
      GO TO 80
   60 COE=1625.
      GO TO 80
   70 COE=500.
   80 CONTINUE
      COQ=COE*HR
      IF(EQUIV.GT.1.) GO TO 110
      IF(EQUIV.LT.0.47) GO TO 100
      IF(EQUIV.GT.0.54) GO TO 90
      CHE=-1100.*EQUIV+628.
      GO TO 120
   90 CHE=1.995E+2+EQUIV*(-4.924E+2+3.161E+2*EQUIV)
      GO TO 120
  100 CHE=110.
      GO TO 120
  110 CHE=23.0
  120 CONTINUE
      CHQ=CHE
      IF(TAIR.LE.200.) GO TO 125
      COT=1.394+TAIR*(-2.355E-3+1.289E-6*TAIR)
      NOT=2.091+TAIR*(-6.874E-3+TAIR*(1.188E-5-3.288E-9*TAIR))
      CHT=1.465+TAIR*(-2.865E-1+TAIR*(2.643E-2-9.318E-4*TAIR))
      GO TO 130
  125 COT=1.
      NOT=1.
      CHT=1.
  130 CONTINUE
      NOPPM=NOQ*NOT
```

PROGRAM LISTING -- COMB3 (Cont'd)

```
      COPPM=CUQ*COT
      CHPPM=CHQ*CHT
      PROD=H2OP+CO2P+N2P+O2P+CHP
*     CHR IS 1HE MOLECULAR WEIGHT OF FUEL
*     WEIGHT OF POLLUTANTS PFR UNIT WEIGHT OF FUEL
      NO=NOPPM*PROD*30.*1.E-6/CHR
      CO=COPPM*PROD*28.*1.E-6/CHR
      CH=CHPPM*PROD*13.*1.E-6/CHR
      IF(FQUIV.LE.1.) GO TO 140
      CH=CHP/CHR
  140 CONTINUF
*     GRAM POLLUTANTS IN DELT SEC
      NOTOT=NO*MF*DELT*(1./2.205E-3)
      COTOT=CO*MF*DELT*(1./2.205E-3)
      CHTOT=CH*MF*DELT*(1./2.205E-3)
      RETURN
      END
```

SUBROUTINE ENERGY

The subroutine ENERGY calculates the enthalpy of the products of combustion.

NOMENCLATURE -- ENERGY

FORTRAN Variables in COMMON:

There is no COMMON block in ENERGY.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
CO2P	Moles of carbon dioxide in products	moles
H	Enthalpy of products of combustion	Btu/lb
H2OP	Moles of water vapor in products	moles
N2P	Moles of nitrogen in products	moles
O2P	Moles of oxygen in products	moles
T	Temperature	°F

PROGRAM LISTING -- ENERGY

```
      SUBROUTINE ENERGY(T,H,H2OP,CO2P,N2P,O2P)
      REAL O2P,N2P
      TR=T+460.
      IF(TR.GT.600.)GO TO 50
      HH2O=(17./6.)*TR
      GO TO 60
   50 HH2O=-3.320E+3+TR*(7.744+5.793E-4*TR)
   60 CONTINUE
      IF(TR.GT.500.)GO TO 700
      HCO2=2.*TR
      GO TO 800
  700 IF(TR.GT.1300.)GO TO 900
      HCO2=(825./80.)*(TR-500.)+1000.
      GO TO 800
  900 HCO2=1.401E+1*TR-9.266E+3
  800 CONTINUE
      IF(TR.GT.500.)GO TO 400
      HO2=2.*TR
      GO TO 500
  400 IF(TR.GT.900.)GO TO 600
      HO2=(25./4.)*(TR-500.)+1000.
      GO TO 500
  600 HO2=8.732*TR-4418.
  500 CONTINUE
      IF(TR.GT.600.)GO TO 100
      HN2=(40./15.)*TR
      GO TO 200
  100 IF(TR.GT.1300.)GO TO 300
      HN2=(7.)*(TR-600.)+1600.
      GO TO 200
  300 HN2=8.337*TR-4572.
  200 CONTINUE
      HTH2O=H2OP*HH2O
      HTCO2=CO2P*HCO2
      HTN2=N2P*HN2
      HTO2=O2P*HO2
      H=HTH2O+HTCO2+HTN2+HTO2
      RETURN
      END
```

SUBROUTINE TRHT

This subroutine TRHT calculates the heat transfer coefficient between the air or combustion gas and the shell or tube wall.

NOMENCLATURE -- TRHT

FORTRAN Variables in COMMON:

There is no COMMON block in TRHT

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
C	Specific heat of air or gas	Btu/lb °F
D	Hydraulic diameter of tube flow passage	in.
G	Mass flow rate	lb/sec in^2
H	Heat transfer coefficient between shell and air or tube and combustion gas	Btu/sec °F
K	Conductivity of air or gas	Btu/hr ft °F
VIS	Viscosity of air or gas	lb/hr ft

PROGRAM LISTING -- TRHT

```
      SUBROUTINE TRHT(G,D,VIS,C,K,H)
      REAL K
      H=(.023)*((3600.*12.*G*D/VIS)**.8)*((C*VIS/K)**.4)*(K/D)
     1*(1./(3600.*12.))
      RETURN
      END
```

Section 10

TRANSMISSION MODEL

Section10

TRANSMISSION MODEL

MAIN PROGRAM -- TRANSM

The transmission model is entitled TRANSM. The model reads data from data file 38, which is entitled Data Input and is discussed with the total systems model, MAINSYS, in Section 13.

NOMENCLATURE -- TRANSM

FORTRAN Variables in COMMON:

There is no COMMON block in TRANSM.

FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
INE	Logic variable to read data	--
R	Engine intake ratio	--
RPME	Engine rpm	rpm
RPMX	Axle rpm	rpm
TENET	Engine torque	ft-lb
TORQX	Axle torque	ft-lb

FORTRAN Variables in READ Statements:

FORTRAN Variable	Definition	Units
GRH	High gear ratio	--
GRL	Low gear ratio	--
GRRE	Rear-end gear ratio	--
R1L	Intake ratio at point 1L*	--
R1U	Intake ratio at point 1U*	--
R2L	Intake ratio at point 2L*	--
R2U	Intake ratio at point 2U*	--

---

*See Volume I, Section 4 for the location of these points.

FORTRAN Variable (Cont'd)	Definition	Units
RPM1L	Axle rpm at point 1L*	rpm
RPM1U	Axle rpm at point 1U*	rpm
RPM2L	Axle rpm at point 2L*	rpm
RPM2U	Axle rpm at point 2U*	rpm

*See Volume I for the location of these points.

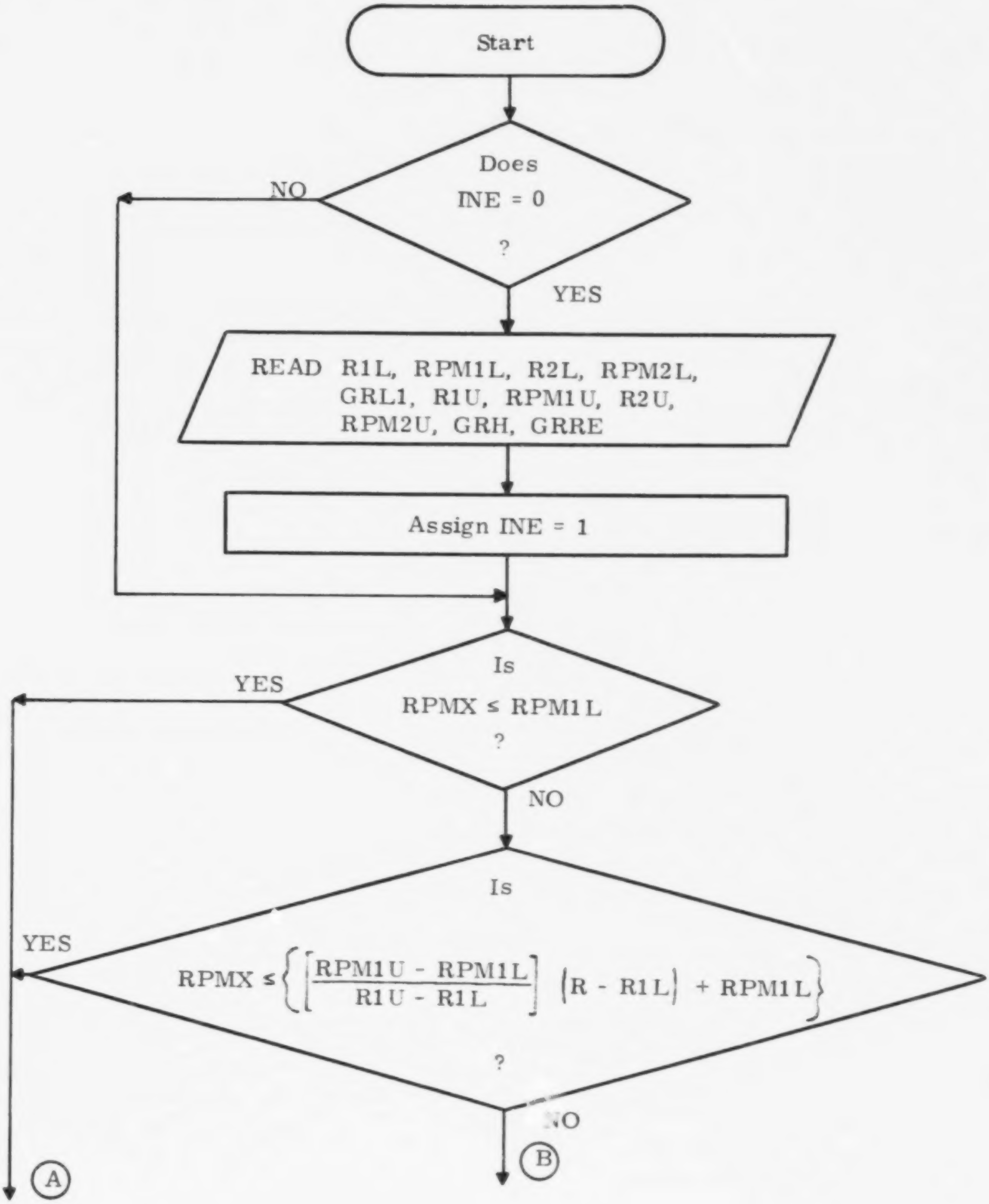
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
GR	Gear ratio	--
HPX	Power required for driving auxiliaries and drive train losses	hp
TLOSS	Torque loss due to driving auxiliaries and drive train losses	ft-lb

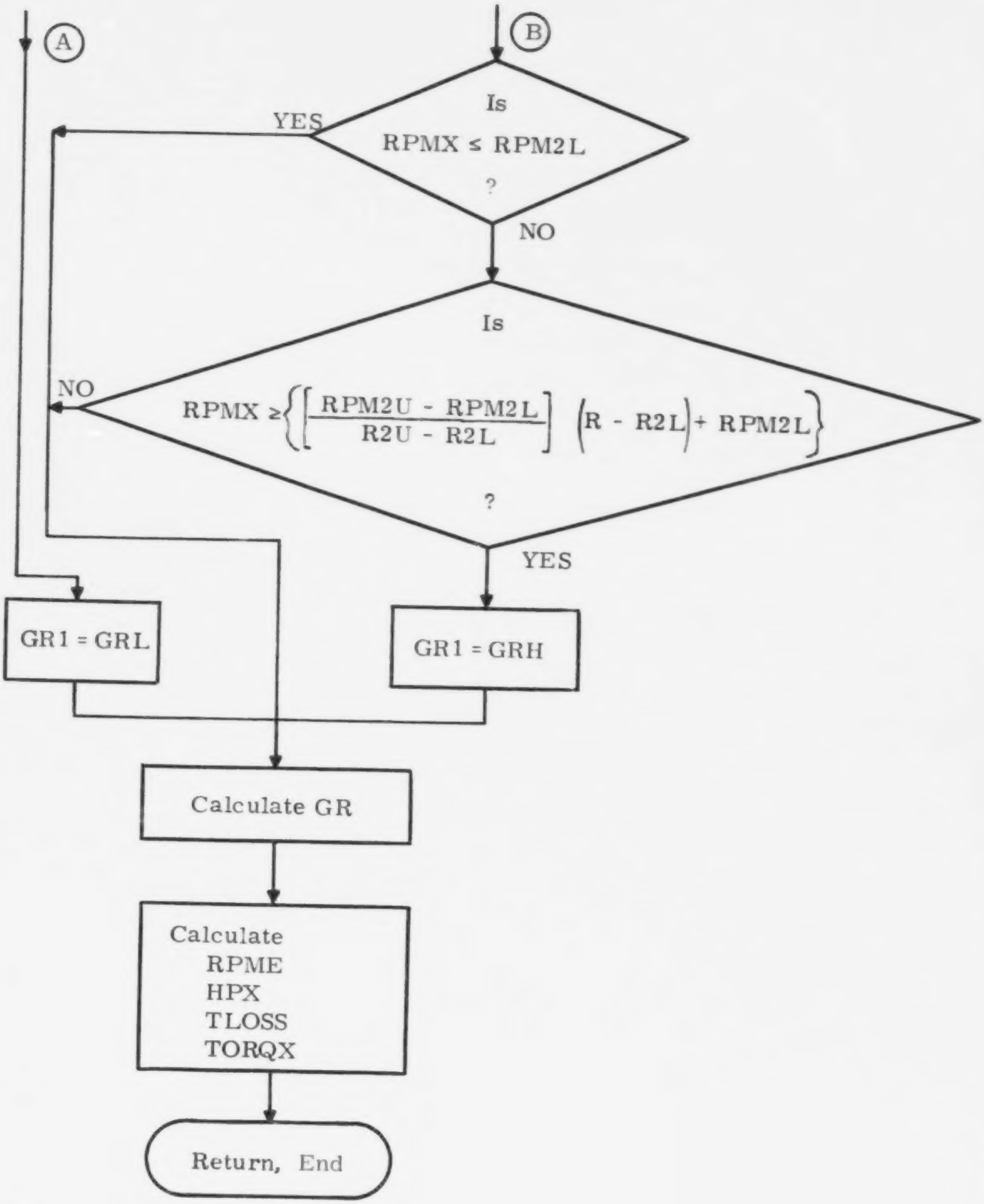
---

*See Volume I, Section 4 for the location of these points.

FLOW DIAGRAM -- TRANSM


Start
Does
INE = 0
?
NO
YES
READ R1L, RPM1L, R2L, RPM2L, GRL1, R1U, RPM1U, R2U, RPM2U, GRH, GRRE
Assign INE = 1
Is
RPMX ≤ RPM1L
?
YES
NO
Is
RPMX ≤ {[RPM1U - RPM1L / R1U - R1L] (R - R1L) + RPM1L}
?
YES
NO
A
B

FLOW DIAGRAM -- TRANSM (Cont'd)


A
B
Is RPMX ≤ RPM2L ?
YES
NO
Is RPMX ≥ {[(RPM2U - RPM2L)/(R2U - R2L)] (R - R2L) + RPM2L} ?
NO
YES
GR1 = GRL
GR1 = GRH
Calculate GR
Calculate RPME HPX TLOSS TORQX
Return, End

PROGRAM LISTING -- TRANSM

```
      SUBROUTINE TRANSM(R,RPMX,TENET,RPME,TORQX,INE)
*     CLUTCH NOT CONSIDERED.  THIS IS CRITICAL AT IDLE CONDITION.
*     MODIFY PROGRAM WHEN CONTROLS ARE INCLUDED.
      IF(INE.NE.0) GO TO 7
      READ(38,5)LINE,R1L,RPM1L,R2L,RPM2L,GRL
      READ(38,5)LINE,R1U,RPM1U,R2U,RPM2U,GRH
      READ(38,5)LINE,GRRE
    5 FORMAT(I6,5F12.5)
      INE=1
    7 CONTINUE
      IF(RPMX.LE.RPM1L) GO TO 10
      IF(RPMX.LE.((RPM1U-RPM1L)/(R1U-R1L))*(R-R1L)+RPM1L) GO TO 10
      IF(RPMX.LE.RPM2L) GO TO 30
      IF(RPMX.GE.((RPM2U-RPM2L)/(R2U-R2L))*(R-R2L)+RPM2L) GO TO 20
      GO TO 30
   10 GR1=GRL
      GO TO 30
   20 GR1=GRH
   30 GR=GRRE*GR1
      RPME=GR*RPMX
      HPX=3.
      TLOSS=HPX*33000./(2.*3.1415*RPMX)
      TORQX=GR*(TENET-TLOSS)
      RETURN
      END
```

Section 11

DRIVER MODEL

Section 11

DRIVER MODEL

MAIN PROGRAM – DRIVER

The DRIVER model is entitled DRIVER. It uses no subroutines.

NOMENCLATURE -- DRIVER

FORTRAN Variables in COMMON:

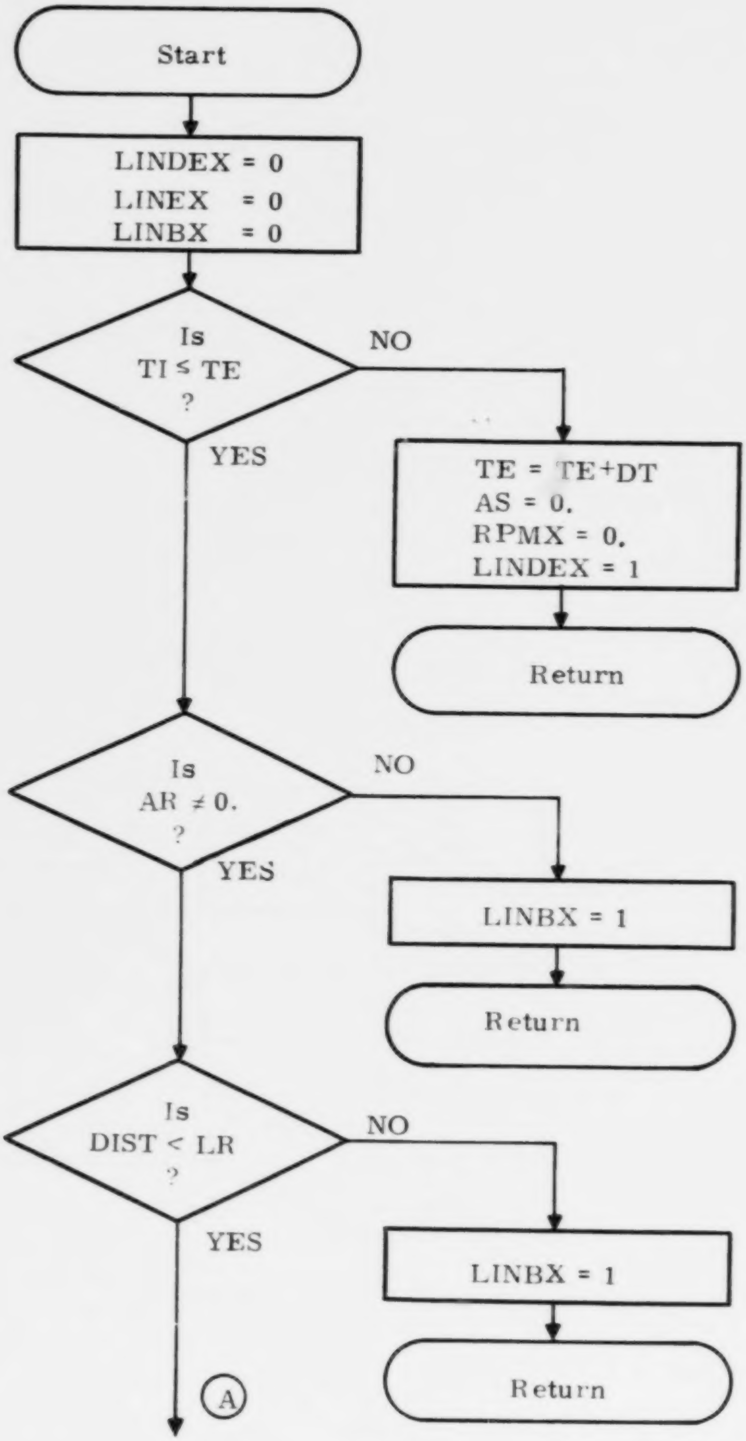
There is no COMMON block in DRIVER.

FORTRAN Variables in Argument List:

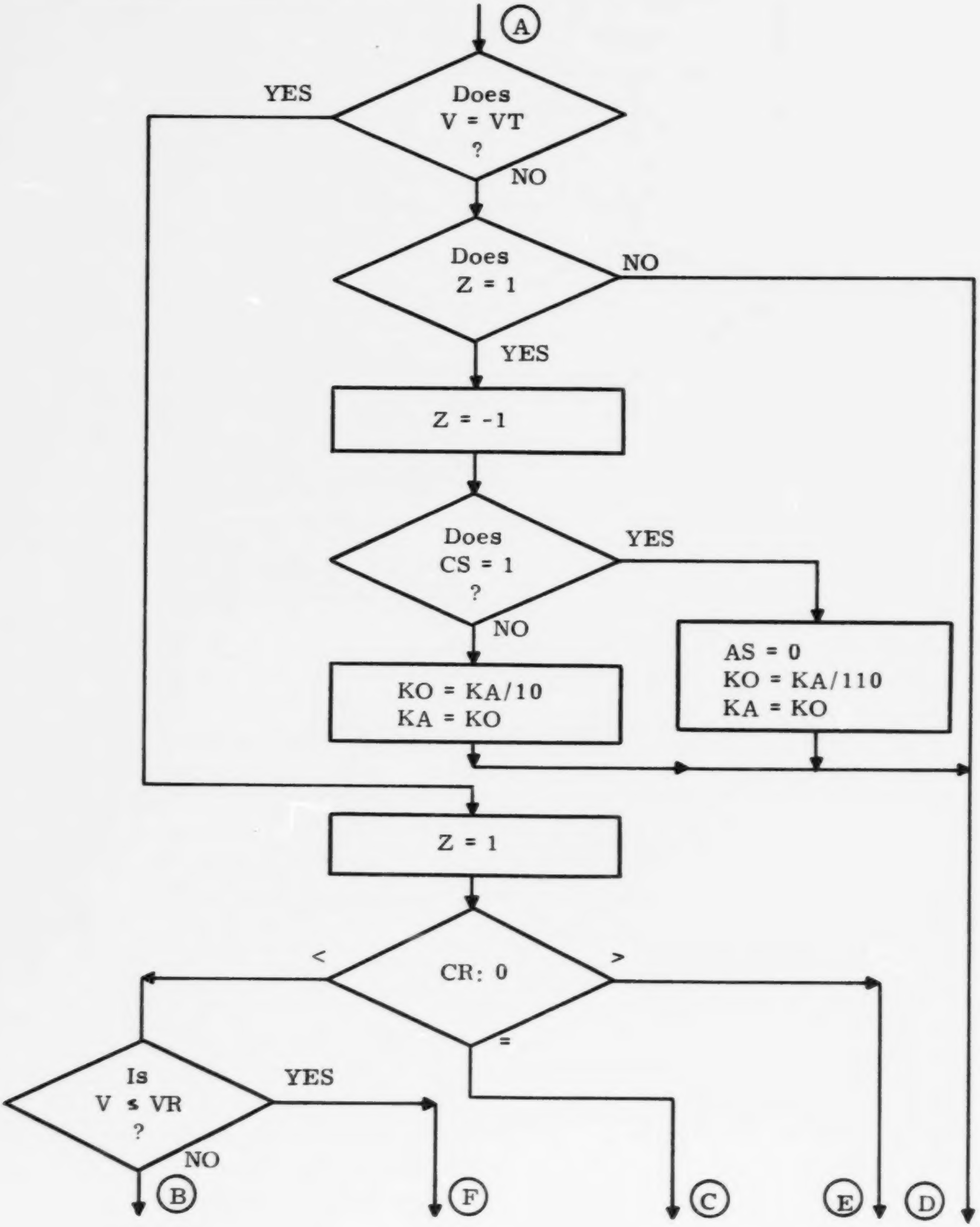
FORTRAN Variable	Definition	Units
A	Vehicle acceleration	ft/sec^2
AA	Linear acceleration of wheel	ft/sec^2
AR	Reference acceleration	ft/sec^2
AS	Accelerator setting	--
CR	Logic variable	
	+1 - indicates acceleration	--
	0 - cruise at constant speed	--
	-1 - indicates deceleration	--
CS	Logic variable for driver action during wheelslip	--
	1 - accelerator setting	
	0, -1 - accelerator held constant	
DIST	Distance traveled	mi
DT	Time step	sec
KA	Accelerator sensitivity (changed internally)	--
KO	Accelerator sensitivity (initial value)	--
LINBX	Logic variable: when = 0, MAINSYS reads new line of data from ROUTE	--
LINDEX	Logic variable: when = 1, vehicle idling	--

FORTRAN Variable (Cont'd)	Definition	Units
LINEX	Logic variable: when ≠ 0, vehicle decelerating; = 0, vehicle accelerating	--
LR	Reference marker location	mi
RADW	Wheel radius	ft
RPMX	Axle rpm	--
TE	Cumulative idle time	sec
TI	Reference idle time	sec
V	Vehicle velocity	mi/hr
VR	Reference vehicle velocity	mi/hr
VT	Wheel velocity	mi/hr
Z	Logic variables used during wheel slip: initially set as 1, reset internally	--

FLOW DIAGRAM -- DRIVER

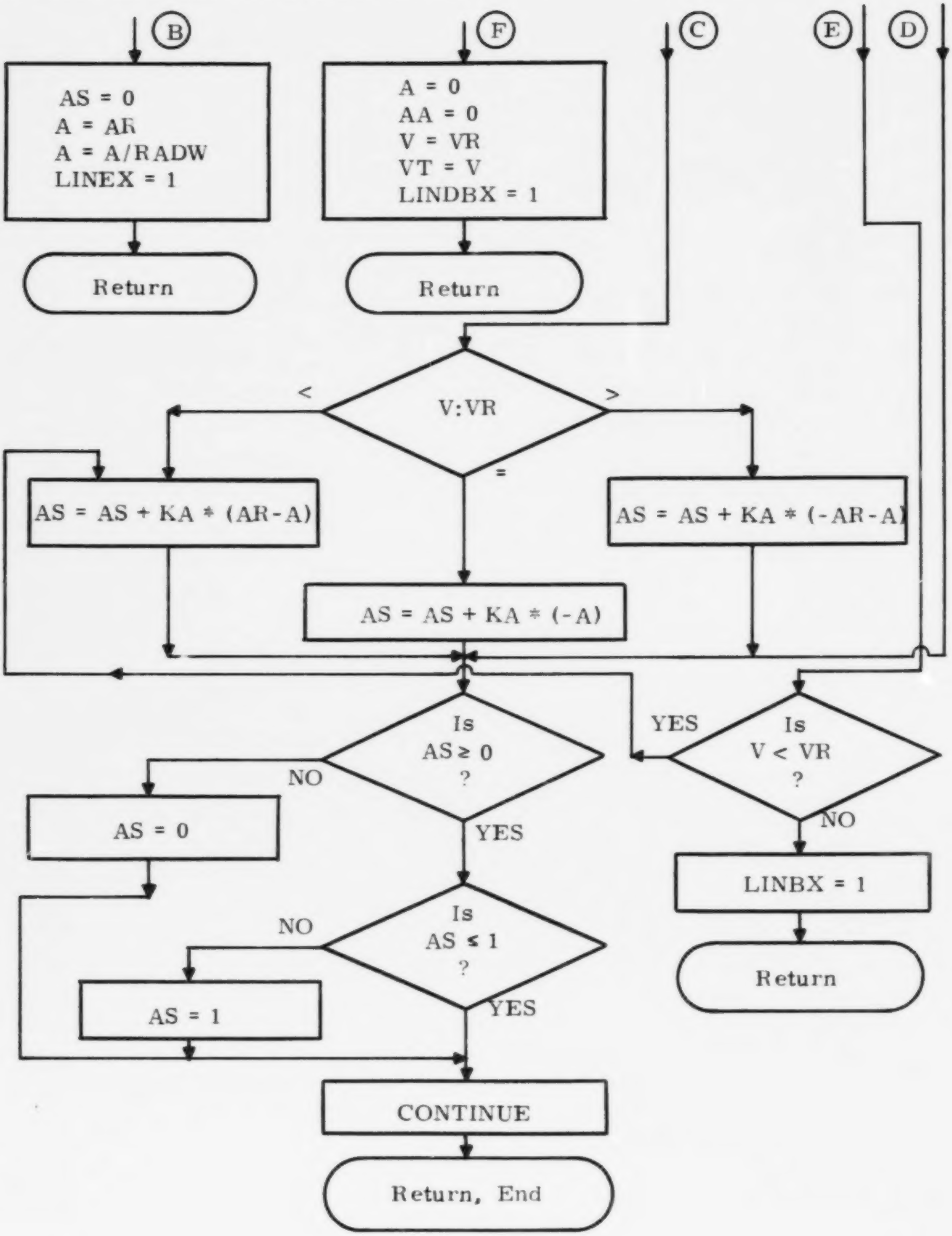

Start
LINDEX = 0
LINEX = 0
LINBX = 0
Is
TI ≤ TE
?
NO
YES
TE = TE+DT
AS = 0.
RPMX = 0.
LINDEX = 1
Return
Is
AR ≠ 0.
?
NO
YES
LINBX = 1
Return
Is
DIST < LR
?
NO
YES
LINBX = 1
Return
A

FLOW DIAGRAM -- DRIVER (Cont'd)



A
Does V = VT ?
YES
NO
Does Z = 1
NO
YES
Z = -1
Does CS = 1 ?
YES
NO
AS = 0
KO = KA/110
KA = KO
KO = KA/10
KA = KO
Z = 1
CR: 0
<
>
=
Is V ≤ VR ?
YES
NO
B
F
C
E
D

FLOW DIAGRAM -- DRIVER (Cont'd)



B
AS = 0
A = AR
A = A/RADW
LINEX = 1
Return
F
A = 0
AA = 0
V = VR
VT = V
LINDBX = 1
Return
C
E
D
V:VR
<
>
=
AS = AS + KA * (AR-A)
AS = AS + KA * (-AR-A)
AS = AS + KA * (-A)
Is AS ≥ 0 ?
NO
YES
AS = 0
Is AS ≤ 1 ?
NO
YES
AS = 1
CONTINUE
Return, End
Is V < VR ?
YES
NO
LINBX = 1
Return

PROGRAM LISTING -- DRIVER

```
      SUBROUTINE DRIVER(TI,TE,AR,DT,DIST,LR,V,VT,Z,CS,KA,CR,VR,
     7RADW,AS,A,LINDEX,LINEX,LINBX,RPMX,KO,AA)
      REAL KA,KO,LR
      INTEGER Z,CR
      LINDEX=0
      LINEX=0
      LINBX=0
      IF(TI.LE.TE) GO TO 25
      TE=TE+DT
      AS=0
      RPMX=0
      LINDEX=1
      RETURN
   25 IF(AR.NE.0.0) GO TO 30
      LINBX=1
      RETURN
   30 IF(DIST.LT.LR) GO TO 32
      LINBX=1
      RETURN
   32 IF(V.EQ.VT) GO TO 50
      IF(Z.EQ.1) GO TO 35
      GO TO 130
   35 Z=-1
      IF(CS.EQ.1.) GO TO 40
      KO=KA/10.
      KA=KO
      GO TO 130
   40 AS=0.
      KO=KA/10.
      KA=KO
      GO TO 130
   50 Z=1
      IF(CR)60,80,120
   60 IF(V.LE.VR) GO TO 70
      AS=0.
      A=AR
      AA=A/RADW
      LINEX=1
      RETURN
   70 A=0.
      AA=0.
      V=VR
      VI=V
      LINBX=1
      RETURN
   80 IF(V-VR)90,100,110
   90 AS=AS+KA*(AR-A)
       GO TO 130
  100 AS=AS+KA*(-A)
      GO TO 130
  110 AS=AS+KA*(-AR-A)
      GO TO 130
  120 IF(V.LT.VR) GO TO 90
      LINBX=1
      RETURN
  130 IF(AS.GE.0.) GO TO 140
      AS=0.
      GO TO 160
  140 IF(AS.LE.1.) GO TO 160
```

PROGRAM LISTING -- DRIVER (Cont'd)

```
      AS=1.
160   CONTINUE
      RETURN
      END
```

Section 12

PARAMETRIC DESIGN PROGRAMS

Section 12

PARAMETRIC DESIGN PROGRAMS

The parametric design programs are employed to determine the component sizes and cycle conditions for a given design power requirement.

MAIN PROGRAM -- EEFF

EEFF calculates the power and cycle efficiency for a system employing a simple reciprocating expander. The intake ratio, piston speed, and inlet pressure are variable, and parametric runs are made by providing appropriate input data.

The program iterates on the condenser temperature, TCOND. The iteration accuracy is set internally by ERROR = .02 and the number of iterations limited by ITER1 = 100. The condenser temperature is determined by scaling from a condenser with a specified heat rate QCONDT, and inlet temperature, TCOST.

EEFF employs the following additional subroutines:

SUPPT
SATP
ENGINE
DOME
PUMP

It should be noted that the argument list and COMMON of subroutine ENGINE must be modified for use with EEFF.

EEFF is currently set up for a Rankine cycle employing a regenerator.

NOMENCLATURE -- EEFF

FORTRAN Variables in COMMON:

The variables NND and IND (used in the COMMON of EEFF) are in the COMMON of MAINSYS, listed and defined in Section 13.

FORTRAN Variables in READ Statements:

FORTRAN Variable	Definition	Units
AP	Piston area	in^2
DPRES	Pressure increment	psi
DR	Intake ratio increment	--
DS	Piston speed increment	ft/min

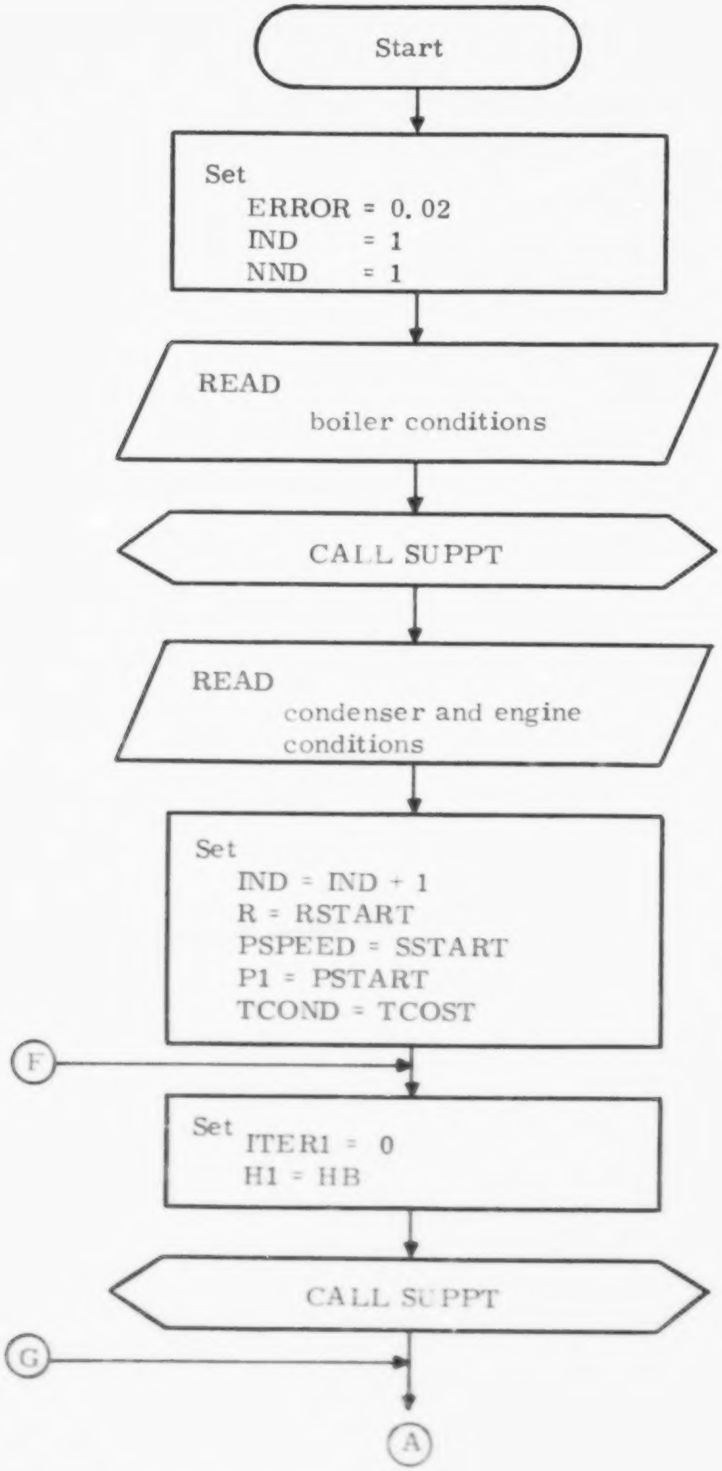
FORTRAN Variable	Definition	Units
EFFBOI	Boiler effectiveness	ft/min
EFFREG	Regenerator effectiveness	--
NP	Number of pistons	--
NQ	Logic variable = 1, bypasses TCOND scaling	--
PB	Boiler pressure	psi
PEND	Final inlet pressure	psi
PSTART	Initial inlet pressure	psi
QCONDE	Condenser design heat rate	Btu/hr
REND	Final intake ratio	--
RSTART	Initial intake ratio	--
SEND	Final piston speed	ft/min
SP1	Piston stroke	in.
SSTART	Initial piston speed	ft/min
TB	Boiler temperature	°F
TCOST	Initial guess at condenser temperature (also condenser design temperature)	°F

Other Selected FORTRAN Variables:

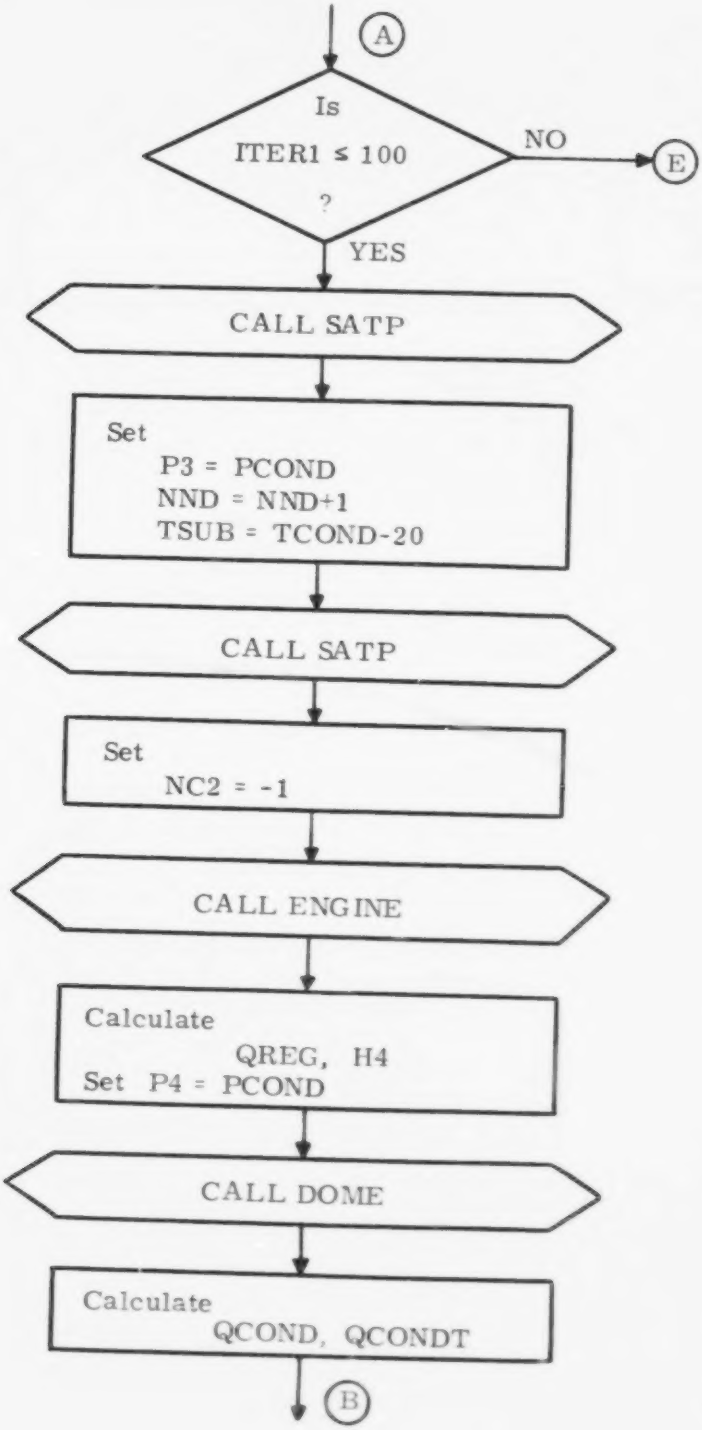
FORTRAN Variable	Definition	Units
EFF	Cycle Efficiency	--
EFFOVC	Overall efficiency	--
H4	Inlet enthalpy condenser	Btu/lb
H8	Enthalpy pump exit	Btu/lb
H9	Enthalpy pump inlet	Btu/lb
HBOIL	Boiler heat rate	Btu/hr
HP	Cycle design power	hp
HPUMP	Pump power	hp
HSUB	Condenser enthalpy outlet	Btu/lb
P4	Condensing pressure	psi
P8	Pressure pump exit	psi

FORTRAN Variable	Definition	Units
P9	Pressure pump inlet	psi
PSUB	Condenser pressure at outlet	psi
QCONDT	Condenser heat rate	Btu/hr
QREG	Regenerator specific heat rate	Btu/lb
RPM	Expander rpm	rpm
TCOND	Condensing temperature	°F
TSUB	Condenser temperature outlet	°F
VSUB	Condenser specific volume outlet	ft^3/lb
WNET	WSHAFT - WP network	Btu/lb
WP	Pump work	Btu/lb
WSHAFT	Expander shaft work	Btu/lb

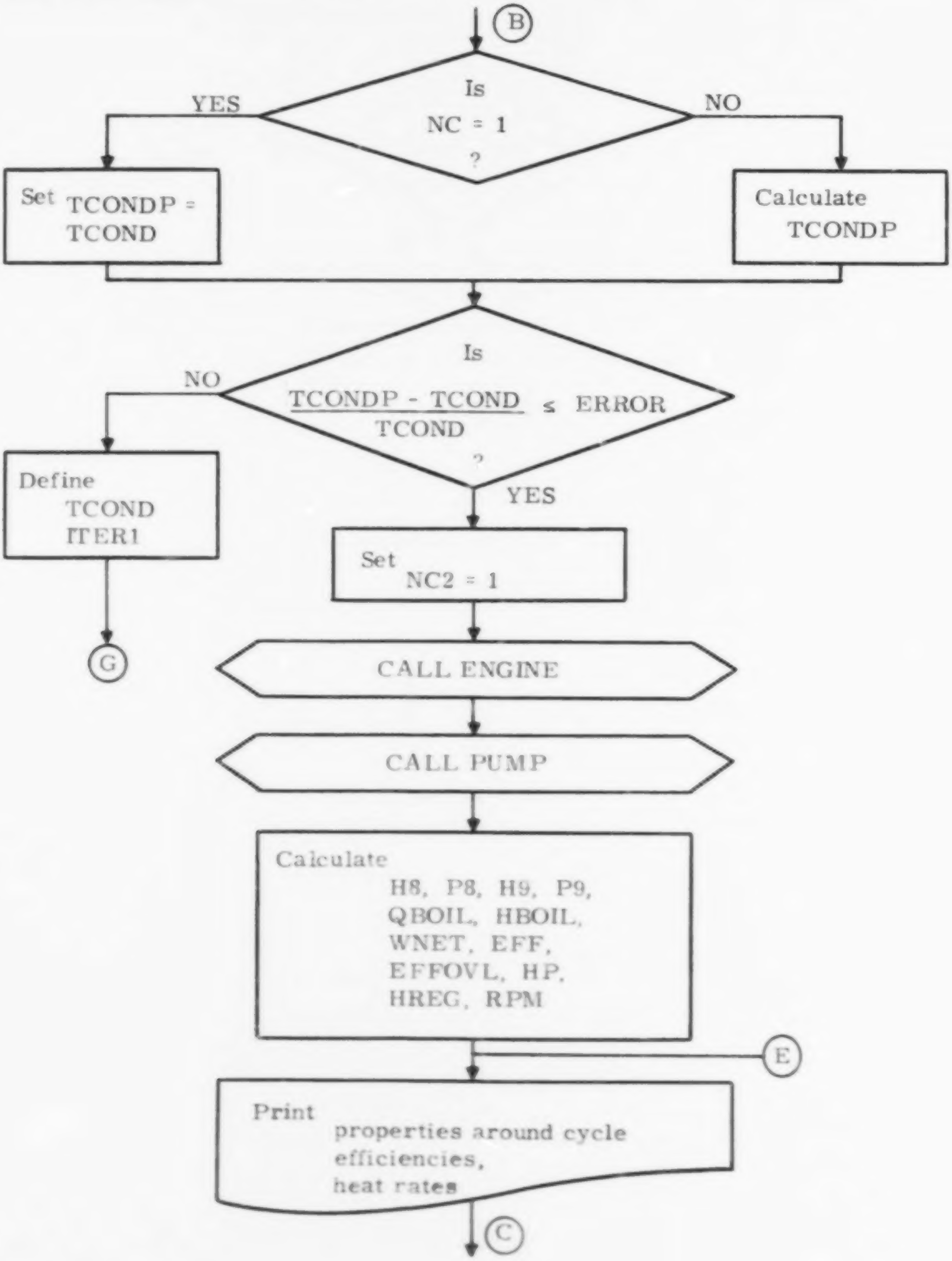
FLOW DIAGRAM -- EEFF


Start
Set
ERROR = 0.02
IND = 1
NND = 1
READ
boiler conditions
CALL SUPPT
READ
condenser and engine conditions
Set
IND = IND + 1
R = RSTART
PSPEED = SSTART
P1 = PSTART
TCOND = TCOST
F
Set
ITER1 = 0
H1 = HB
CALL SUPPT
G
A

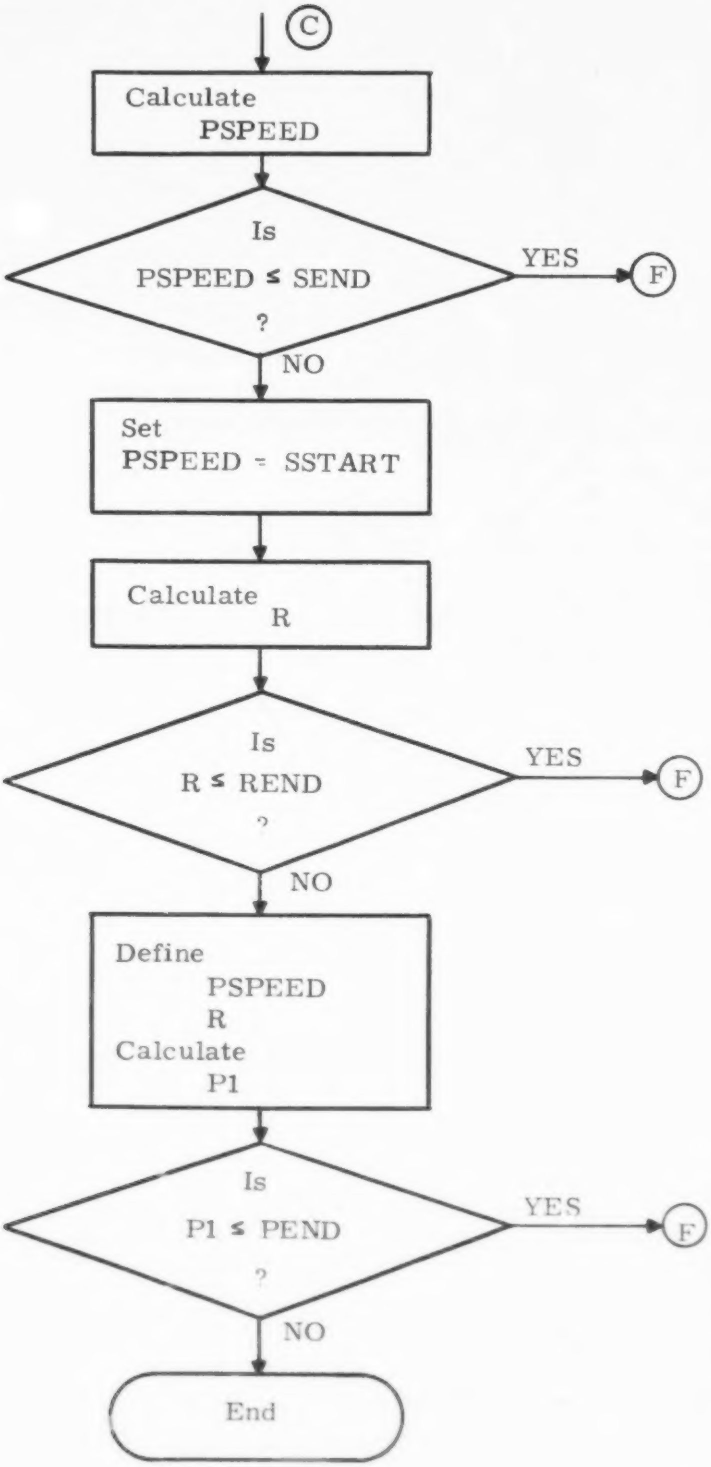
FLOW DIAGRAM -- EEFF (Cont'd)


A
Is
ITER1 ≤ 100
?
NO
E
YES
CALL SATP
Set
P3 = PCOND
NND = NND+1
TSUB = TCOND-20
CALL SATP
Set
NC2 = -1
CALL ENGINE
Calculate
QREG, H4
Set P4 = PCOND
CALL DOME
Calculate
QCOND, QCONDT
B

FLOW DIAGRAM -- EEFF (Cont'd)


B
Is NC = 1 ?
YES
NO
Set TCONDP = TCOND
Calculate TCONDP
Is $\frac{TCONDP - TCOND}{TCOND} \le$ ERROR ?
NO
YES
Define TCOND ITER1
G
Set NC2 = 1
CALL ENGINE
CALL PUMP
Calculate H8, P8, H9, P9, QBOIL, HBOIL, WNET, EFF, EFFOVL, HP, HREG, RPM
E
Print properties around cycle efficiencies, heat rates
C

FLOW DIAGRAM -- EEFF (Cont'd)



C
Calculate PSPEED
Is PSPEED ≤ SEND ?
YES
F
NO
Set PSPEED = SSTART
Calculate R
Is R ≤ REND ?
YES
F
NO
Define PSPEED R
Calculate P1
Is P1 ≤ PEND ?
YES
F
NO
End

PROGRAM LISTING -- EEFF

```
*        ENGINE EFFICIENCY CALCULATION
         COMMON NND,IND
         REAL NP,IMEP
         FILENAME FILE2
         ERROR=0.02
         IND=1;NND=1
*        READ IN DATA BOILER PRESSURE, TEMPERATURE, INTAKE RATIO,
*        AND PISTON SPEED, CONDENSER TEMPERATURE
         READ("FILE2",200)LINE,AP,PB,TB,NP
         CALL SUPPT(PB,TB,HB,SB,VB,1)
         READ("FILE2",200)LINE,EFFREG,EFFBOI
         READ("FILE2",200)LINE,NQ,TCOST,QCONDE
         READ("FILE2",200)LINE,RSTART,REND,SSTART,SEND
         READ("FILE2",200)LINE,PSTART,PEND
         READ("FILE2",200)LINE,DR,DS,DPRES
         READ("FILE2",200)LINE,SP1
         IND=IND+1
         R=RSTART;PSPEED=SSTART;P1=PSTART
         TCOND=TCOST
   20    ITER1=0
         H1=HB
         CALL SUPPT(P1,T1,H1,S1,V1,3)
   30    IF(ITER1.LE.100) GO TO 40
         GO TO 400
   40    CONTINUE
         CALL SATP(PCOND,TCOND,VCONDL,VCONDV,HL,HV,0)
         P3=PCOND
         NND=NND+1
         TSUB=TCOND-20.
         CALL SATP(PSUB,TSUB,VSUB,X,HSUB,Y2,0)
         NC2=-1
         CALL ENGINE(R,PSPEED,NC2,NP,AP,P1,T1,H1,S1,V1,P3,T3,H3,
+        S3,V3,X3,FLOWR,WES,WA,EFFTH,IMEP,EFFME,EFFALL,WSHAFT)
         QREG=EFFREG*(H3-HV)
         H4=H3-QREG
         P4=PCOND
         CALL DOME(P4,H4,T4,V4,X4,0)
         QCOND=H4-HSUB
         QCONDT=FLOWR*QCOND
         IF(NQ.EQ.1) GO TO 58
         TCONDP=95.+(TCOST-95.)*(QCONDT/QCONDE)
         GO TO 59
   58    TCONDP=TCOND
   59    CONTINUE
         IF (ABS((TCONDP-TCOND)/TCOND).LE.ERROR) GO TO 166
         TCOND=TCONDP
         ITER1=ITER1+1
         GO TO 30
  166    CONTINUE
         NC2=1
         CALL ENGINE(R,PSPEED,NC2,NP,AP,P1,T1,H1,S1,V1,P3,T3,H3,
+        S3,V3,X3,FLOWR,WES,WA,EFFTH,IMEP,EFFME,EFFALL,WSHAFT)
  170    CALL PUMP(PCOND,PB,VSUB,FLOWR,PSPEED,HPUMP,WP)
         H8=HSUB+WP
         P8=PB
         H9=H8+QREG
         P9=PB
         QBOIL=H1-H9
         HBOIL=FLOWR*QBOIL
```

PROGRAM LISTING -- EEFF (Cont'd)

```
00620 *
00630 *      NET POWER OUTPUT
00640 *
00650        WNET=WSHAFT-WP
00660        EFF=WNET/QBOIL
00670        EFFOVL=EFF*EFFBOI
00680        HP=WNET*FLOWR/2545.
00690        HREG=FLOWR*QREG
00700        RPM=6.*PSPEED/SP1
00710   400  CONTINUE
00720        PRINT:"QCOND,QCONDT,TCOND",QCOND,QCONDT,TCOND
00730        PRINT:"WP,HPUMP,H8,P8,H9,P9",WP,HPUMP,H8,P8,H9,P9
00733        PRINT:"PSUB,TSUB,HSUB,VSUB",PSUB,TSUB,HSUB,VSUB
00735      PRINT:"P4,H4",P4,H4
00740        PRINT:"QBOIL,HBOIL",QBOIL,HBOIL
00750        PRINT:"QREG",QREG
00760        PRINT:"WNET,EFF,EFFOVL,HP,RPM",WNET,EFF,EFFOVL,HP,RPM
00770        PRINT: "   "
00780        PRINT: "   "
00790        PRINT: "   "
00800        PSPEED=PSPEED+DS
00810        IF (PSPEED.LE.SEND) GO TO 20
00820        PSPEED=SSTART
00830   410  R=R+DR
00840        IF (R.LE.REND) GO TO 20
00850        PSPEED=SSTART; R=RSTART
00860        P1=P1+DPRES
00870        IF(P1.LE.PEND) GO TO 20
00880   200  FORMAT(V)
00890   600  CONTINUE
00900        END
```

MAIN PROGRAM -- ECOMP

ECOMP calculates the power and cycle efficiency for a compound reciprocating expander with an energy accumulation between the first and second stages. It is analogous to EEFF, but with two stages rather than one (refer to the preceding description of EEFF for further details).

ECOMP employs the following subroutines:

- SUPPT
- SATP
- ENGINE
- PUMP

FORTRAN Variables in COMMON:

The variables NND and IND, used in the COMMON of ECOMP, are in the COMMON of MAINSYS, listed and defined in Section 13.

FORTRAN Variables Input through READ Statement:

FORTRAN Variable	Definition	Units
AP1	Piston area, stage 1	in.^{2}
AP2	Piston area, stage 2	in.^{2}
DPRES	Inlet pressure increment	psi
DR2	Intake ratio increment, stage 2	--
DS	Piston speed increment	ft/min
NP1	Piston number, stage 1	--
NP2	Piston number, stage 2	--
NQ	Logic variable: = 1, bypass TCOND scaling	
PEND	Final inlet pressure	psi
PI	Boiler pressure	psi
PSTART	Initial inlet pressure	psi
QCONDE	Condenser design heat rate	Btu/hr
R1START	Initial intake ratio, stage 1	--
R2START	Initial intake ratio, stage 2	--
R2END	Final intake ratio, stage 2	--
SEND	Final piston speed	ft/min
SP1	Piston stroke, stage 1	in.

FORTRAN Variable	Definition	Units
SP2	Piston stroke, stage 2	in.
SSTART	Initial piston speed	ft/min
TAMB	Ambient air temperature	°F
TCOST	Initial guess at condenser temperature (also condenser design temperature)	°F

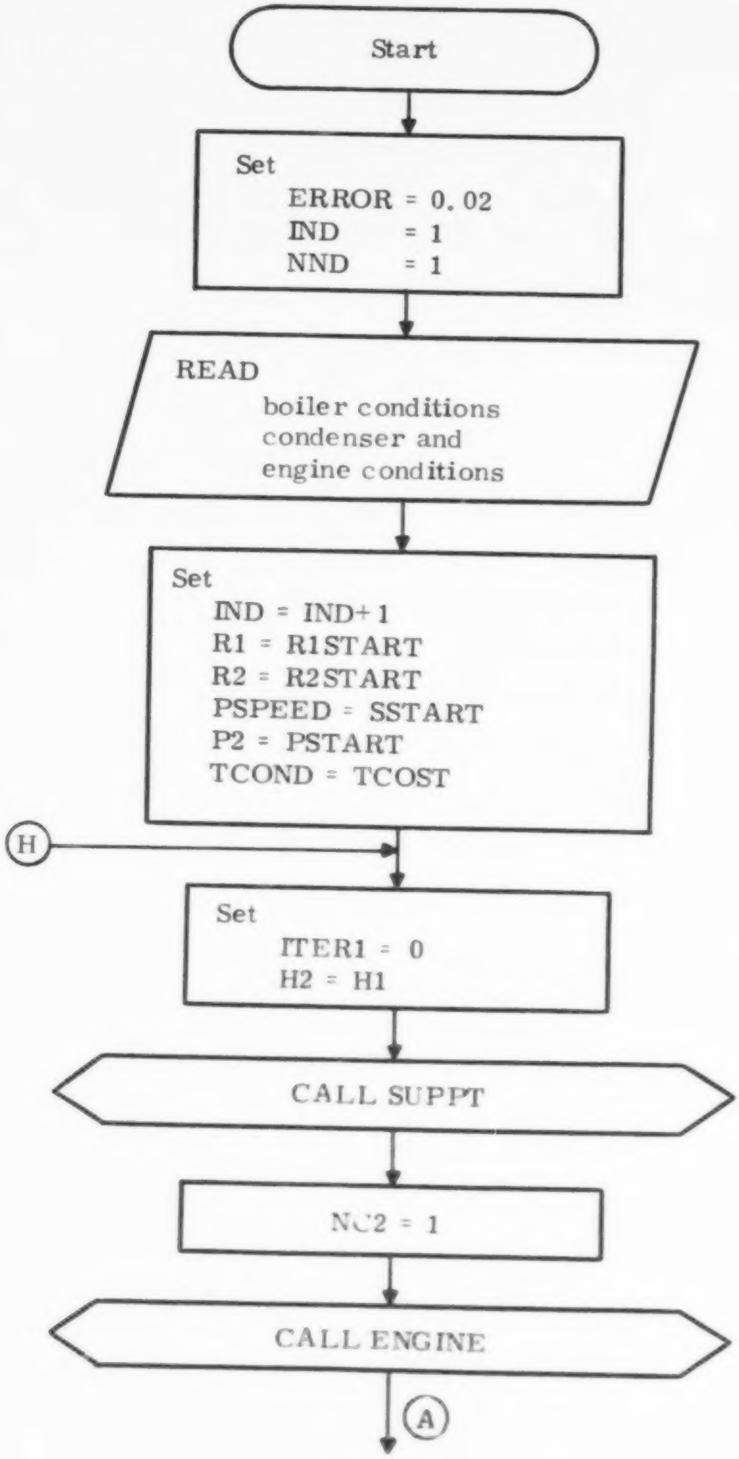
Other Selected FORTRAN Variables:

FORTRAN Variable*	Definition	Units
H5	Enthalpy, condenser pump outlet	Btu/lb
H6	Enthalpy, boiler pump inlet	Btu/lb
H7	Enthalpy, boiler inlet	Btu/lb
HPUMP1	Pump power, condenser pump	hp
HPUMP2	Pump power, boiler pump	hp
P5	Pressure, condenser pump outlet	psi
P6	Pressure, boiler pump inlet	psi
P7	Pressure, boiler inlet	psi
WP1	Pump work, condenser pump	Btu/lb
WP2	Pump work, boiler pump	Btu/lb

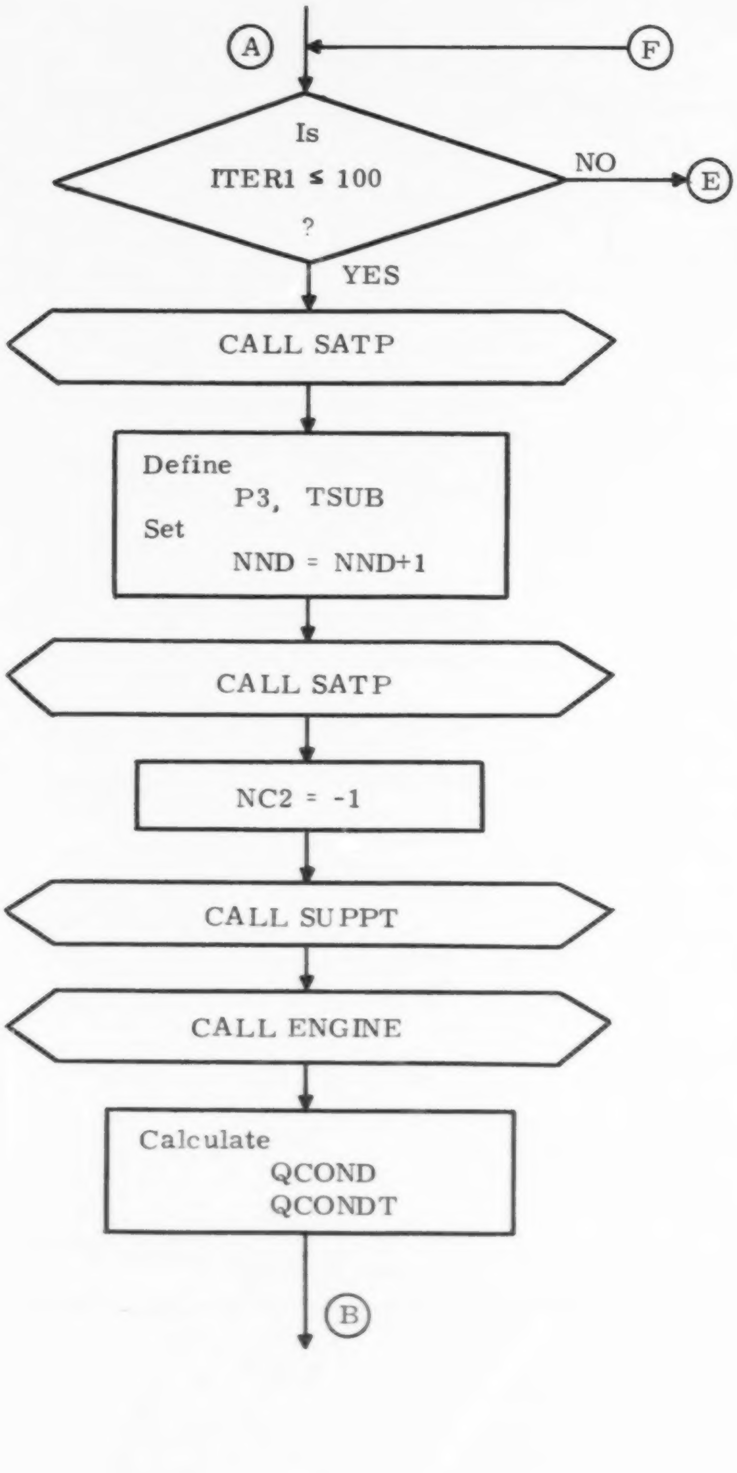
---

*See subroutine EEFF for other variables.

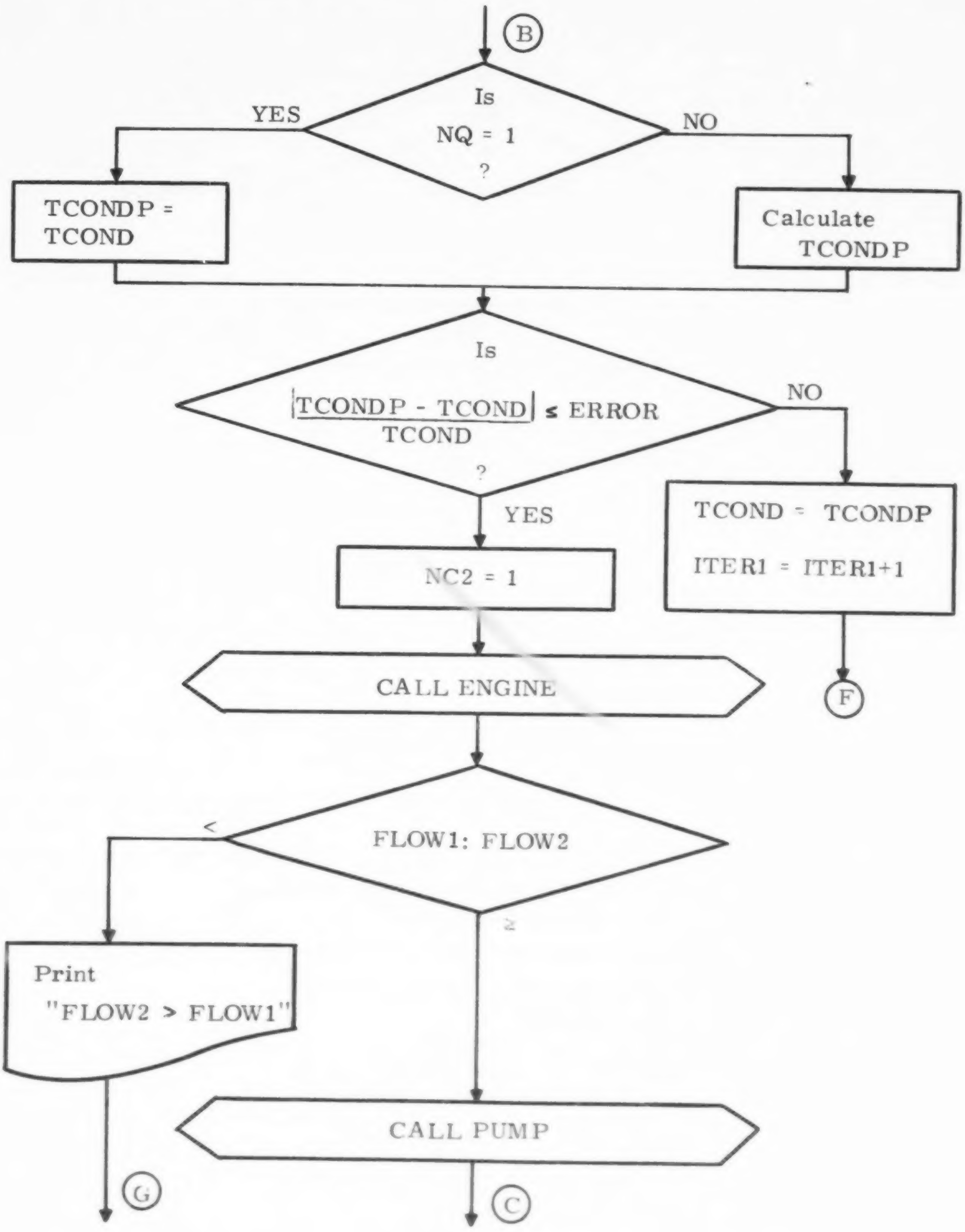
FLOW DIAGRAM -- ECOMP


Start
Set
ERROR = 0. 02
IND = 1
NND = 1
READ
boiler conditions
condenser and
engine conditions
Set
IND = IND+1
R1 = R1START
R2 = R2START
PSPEED = SSTART
P2 = PSTART
TCOND = TCOST
H
Set
ITER1 = 0
H2 = H1
CALL SUPPT
NC2 = 1
CALL ENGINE
A

FLOW DIAGRAM -- ECOMP (Cont'd)

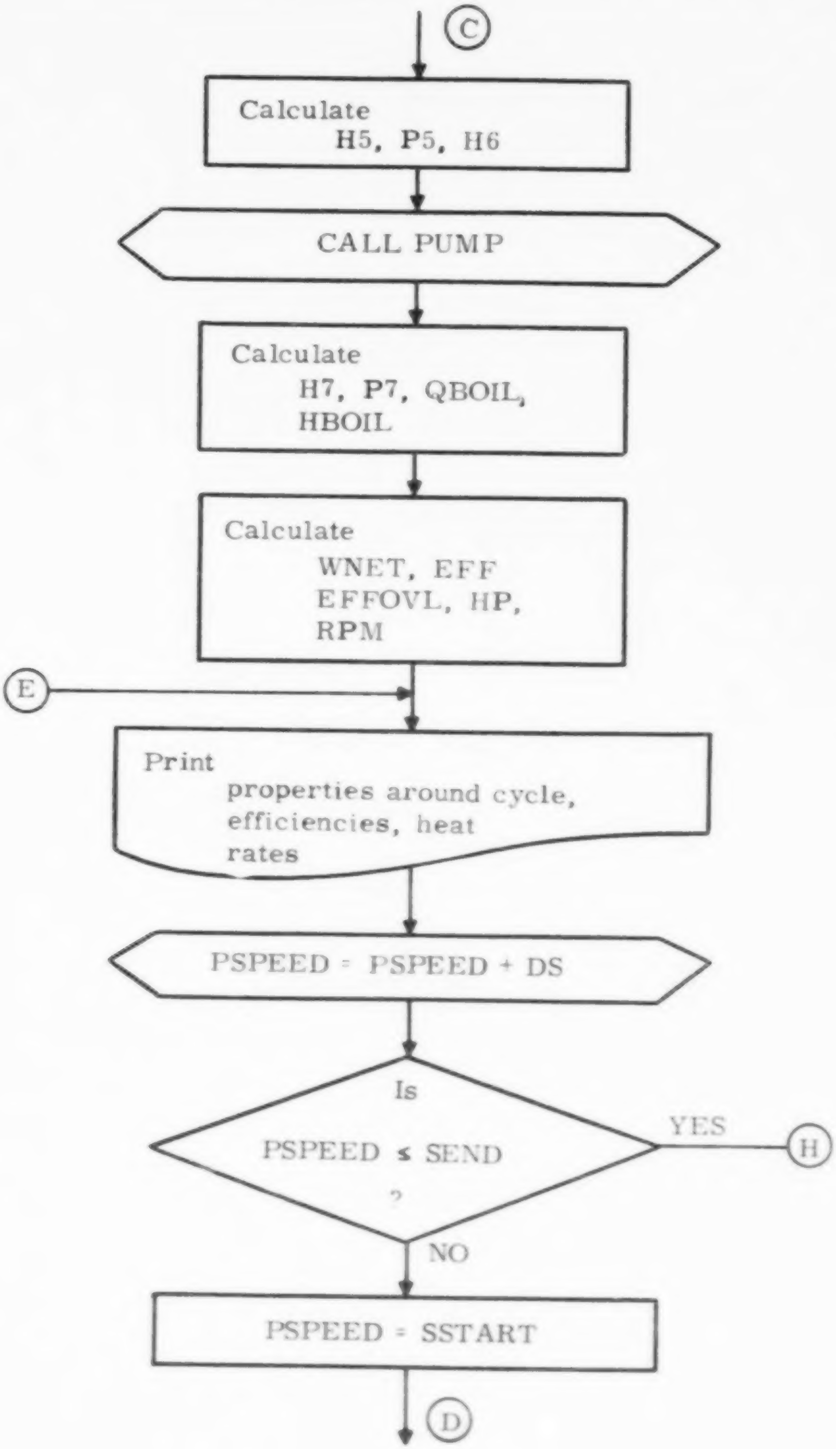

A
F
Is
ITER1 ≤ 100
?
NO
E
YES
CALL SATP
Define
P3, TSUB
Set
NND = NND+1
CALL SATP
NC2 = -1
CALL SUPPT
CALL ENGINE
Calculate
QCOND
QCONDT
B

FLOW DIAGRAM -- ECOMP (Cont'd)

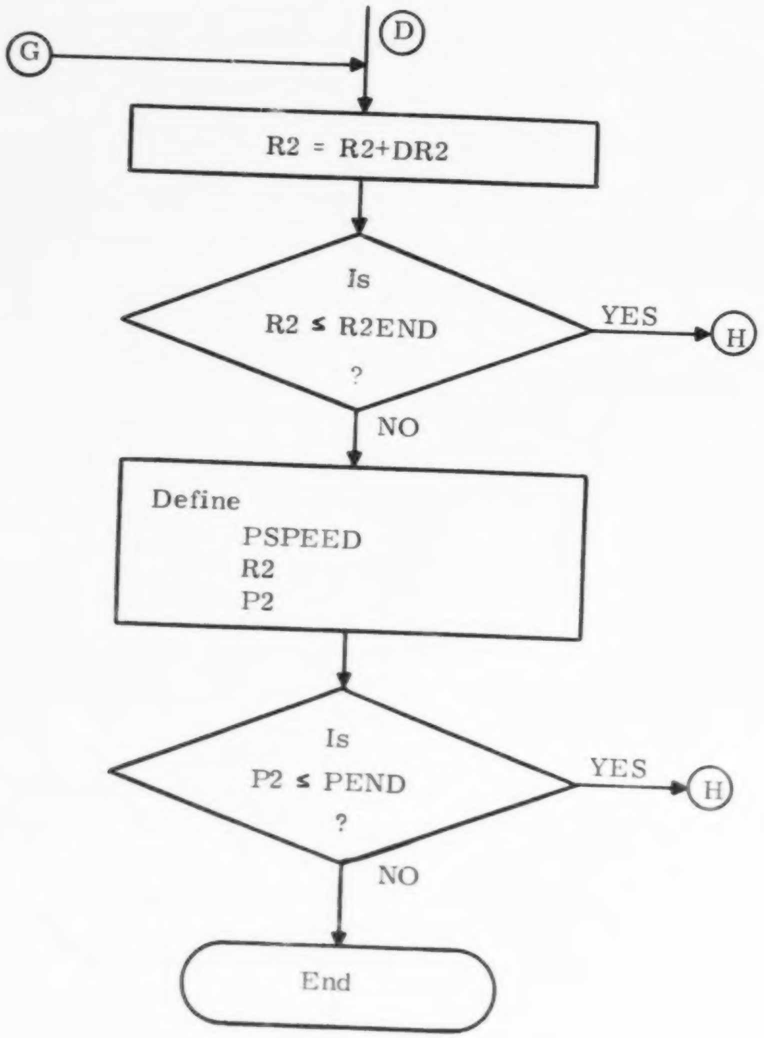


B
Is NQ = 1 ?
YES
NO
TCONDP = TCOND
Calculate TCONDP
Is $\frac{|TCONDP - TCOND|}{TCOND} \leq$ ERROR ?
NO
YES
NC2 = 1
TCOND = TCONDP
ITER1 = ITER1+1
F
CALL ENGINE
FLOW1: FLOW2
<
≥
Print "FLOW2 > FLOW1"
CALL PUMP
G
C

FLOW DIAGRAM -- ECOMP (Cont'd)


C
Calculate H5, P5, H6
CALL PUMP
Calculate H7, P7, QBOIL, HBOIL
Calculate WNET, EFF EFFOVL, HP, RPM
E
Print properties around cycle, efficiencies, heat rates
PSPEED = PSPEED + DS
Is PSPEED ≤ SEND ?
YES
H
NO
PSPEED = SSTART
D

FLOW DIAGRAM -- ECOMP (Cont'd)


D
G
R2 = R2+DR2
Is
R2 ≤ R2END
?
YES
H
NO
Define
PSPEED
R2
P2
Is
P2 ≤ PEND
?
YES
H
NO
End

PROGRAM LISTING -- ECOMP

```
*      COMPOUND ENGINE PROGRAM
       COMMON NND,IND
       REAL NP1,NP2,IMEP1,IMEP2
       FILENAME FILE3
       ERROR=0.02
       IND=1;NND=1
*      READ BOILER PRESSURE,TEMPERATURE,BOILER EFFECTIVENESS.
*      PISTON AREA STROKE AND NUMBER FIRST AND SECOND STAGE.
*      CONDENSER TEMPERATURE,AMBIENT TEMPERATURE,INLET PRESSURE
*      SECOND STAGE.
       READ("FILE3",200)LINE,P1,T1,EFFBOI
       CALL SUPPT(P1,T1,H1,S1,V1,1)
       READ("FILE3",200)LINE,AP1,SP1,NP1,AP2,NP2
       READ("FILE3",200)LINE,NQ,TCOST,QCONDE,TAMB
       READ("FILE3",200)LINE,PI
       READ("FILE3",200)LINE,R1START
       READ("FILE3",200)LINE,R2START,R2END,DR2
       READ("FILE3",200)LINE,PSTART,PEND,DPRES
       READ("FILE3",200)LINE,SSTART,SEND,DS
       IND=IND+1
       R1=R1START;R2=R2START;PSPEED=SSTART;P2=PSTART
       TCOND=TCOST
    20 ITER1=0
       H2=H1
       CALL SUPPT(P2,T2,H2,S2,V2,3)
       NC2=1
       CALL ENGINE(R1,PSPEED,NC2,NP1,AP1,P2,T2,H2,S2,V2,PI,TI,
+      HI,SI,VI,XI,FLOW1,WFS1,WA1,EFFTH1,IMEP1,EFFME1,EFFAL1,
+      WSHAFT1)
    30 IF(ITER1.LE.100) GO  TO 40
       GO TO 400
    40 CONTINUE
       CALL SATP(PCOND,TCOND,VCONDL,VCONDV,HL,HV,0)
       P3=PCOND
       NND=NND+1
       TSUB=TCOND-20.
       CALL SATP(PSUB,TSUB,VSUB,X,HSUB,Y2,0)
       NC2=-1
       CALL SUPPT(PI,TI,HI,SI,VI,3)
       CALL ENGINE(R2,PSPEED,NC2,NP2,AP2,PI,TI,HI,SI,VI,P3,T3,
+      H3,S3,V3,X3,FLOW2,WFS2,WA2,EFFTH2,IMEP2,EFFME2,EFFAL2,
+      WSHAFT2)
       QCOND=H3-HSUB
       QCONDT=FLOW2*QCOND
       IF(NQ.EQ.1) GO TO 58
       TCONDP=TAMB+(TCOST-TAMB)*(QCONDT/QCONDE)
       GO TO 59
    58 TCONDP=TCOND
    59 CONTINUE
       IF(ABS((TCONDP-TCOND)/TCOND).LE.ERROR) GO TO 166
       TCOND=TCONDP
       ITER1=ITER1+1
       GO TO 30
   166 CONTINUE
       NC2=1
       CALL ENGINE(R2,PSPEED,NC2,NP2,AP2,PI,TI,HI,SI,VI,P3,T3,
+      H3,S3,V3,X3,FLOW2,WFS2,WA2,EFFTH2,IMEP2,EFFME2,EFFAL2,
+      WSHAFT2)
       IF(FLOW1-FLOW2)300,310,310
```

```
00600  300  PRINT:"FLOW2>FLOW1"
00610       GO TO 410
00620  310  CONTINUE
00630  170  CALL PUMP(PCOND,P1,VSUB,FLOW2,PSPEED,HPUMP1,WP1)
00640       H5=HSUB+WP1
00650       P5=P1;P6=P1
00660       H6=((FLOW1-FLOW2)*H1+FLOW2*H5)/FLOW1
00670       CALL PUMP(P1,P1,VSUB,FLOW1,PSPEED,HPUMP2,WP2)
00680       H7=H6+WP2
00690       P7=P1
00700       QBOIL=H1-H7
00710       HBOIL=FLOW1*QBOIL
00720 *
00730 *     NET POWER OUTPUT
00740 *
00750       WNET=WSHAFT1+WSHAFT2-WP1-WP2
00760       EFF=WNET/QBOIL
00770       EFFOVL=EFF*EFFBOI
00780       HP=((WSHAFT1-WP2)*FLOW1+(WSHAFT2-WP1)*FLOW2)/2545.
00790       RPM=6.*PSPEED/SP1
00800  400  CONTINUE
00810       PRINT:"QCOND,QCONDT,TCOND",QCOND,QCONDT,TCOND
00820       PRINT:"WP1,HPUMP1,H5,P5,H6,P6",WP1,HPUMP1,H5,P5,H6,P6
00830       PRINT:"WP2,HPUMP2,H7,P7",WP2,HPUMP2,H7,P7
00840       PRINT:"PSUB,TSUB,VSUB,HSUB",PSUB,TSUB,VSUB,HSUB
00850       PRINT:"QBOIL,HBOIL",QBOIL,HBOIL
00860       PRINT:"WNET,EFF,EFFOVL,HP,RPM",WNET,EFF,EFFOVL,HP,RPM
00870       PSPEED=PSPEED+DS
00880       IF(PSPEED.LE.SEND) GO TO 20
00890       PSPEED=SSTART
00900  410  R2=R2+DR2
00910       IF(R2.LE.R2END)GO TO 20
00920       PSPEED=SSTART;R2=R2START
00930       P2=P2+DPRES
00940       IF(P2.LE.PEND) GO TO 20
00950  200  FORMAT(V)
00960  600  CONTINUE
00970       END
```

MAIN PROGRAM -- TSIZE

TSIZE calculates the turbine rotor diameter, blade height, tip clearance, cycle efficiency, and properties around the cycle. The boiler conditions, turbine horsepower, and efficiency are specified by the user.

The following parameters are set internally:

GAMMA = 1.02
GASC = 3.72
DS = 1.3
NS = 60

TSIZE employs the following subroutines:

SUPPT
SATP

NOMENCLATURE -- TSIZE

FORTRAN Variables in COMMON:

The FORTRAN variables in the COMMON of TSIZE are in the COMMON of MAINSYS.

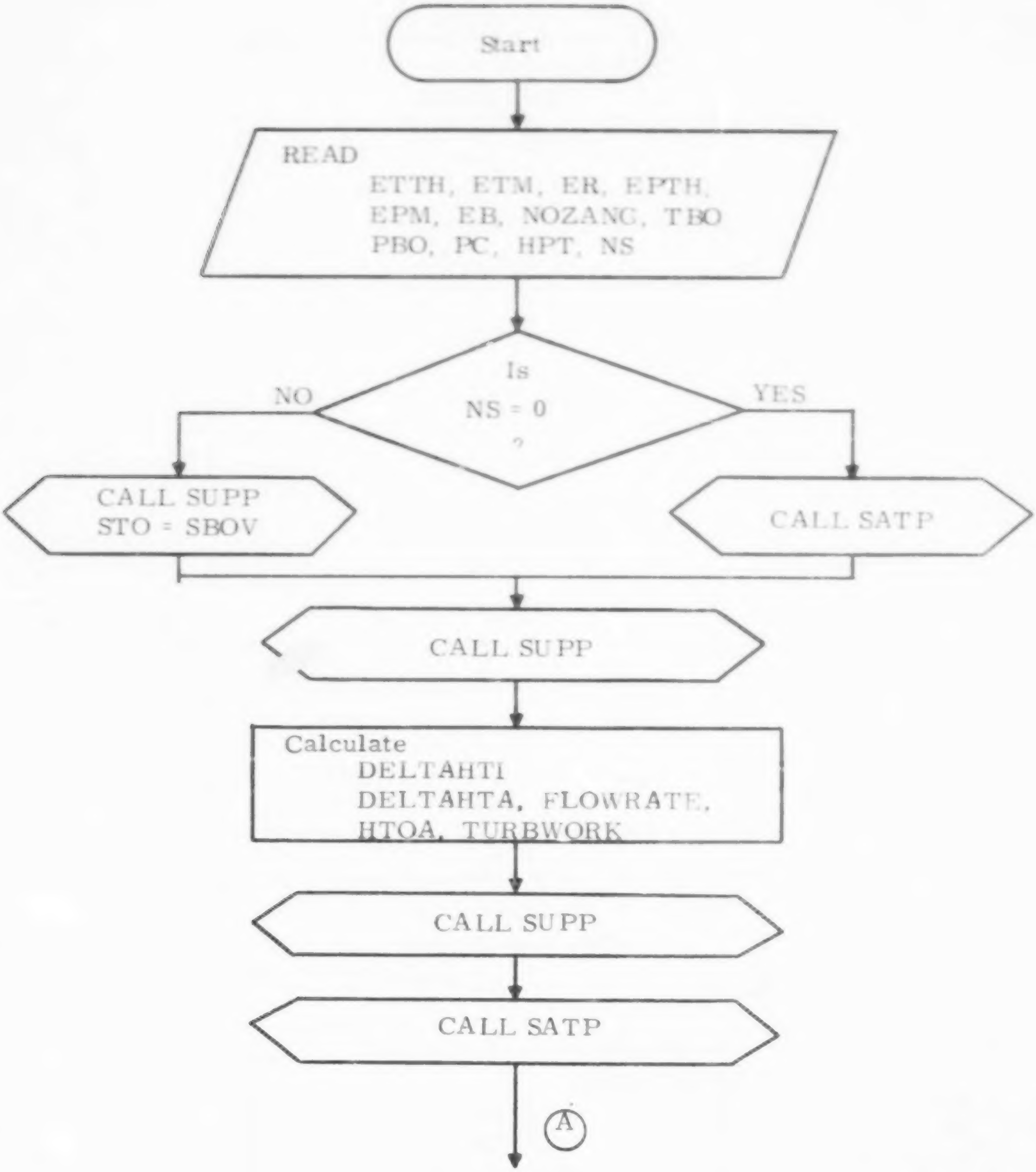
FORTRAN Variables Input Through READ Statements:

FORTRAN Variable	Definition	Units
EB	Boiler effectiveness	--
EPM	Pump mechanical efficiency	--
EPTH	Pump thermal efficiency	--
ER	Regenerator effectiveness	--
ETM	Turbine mechanical efficiency	--
ETTH	Turbine thermal efficiency	--
HPT	Turbine power	hp
NOZANG	Nozzle angle	radians
NS	Logic variable = 0 - saturated boiler outlet ≠ 0 - superheated boiler outlet	--
PBO	Boiler pressure	atm
PC	Condenser pressure	atm
TBO	Boiler temperature	°C

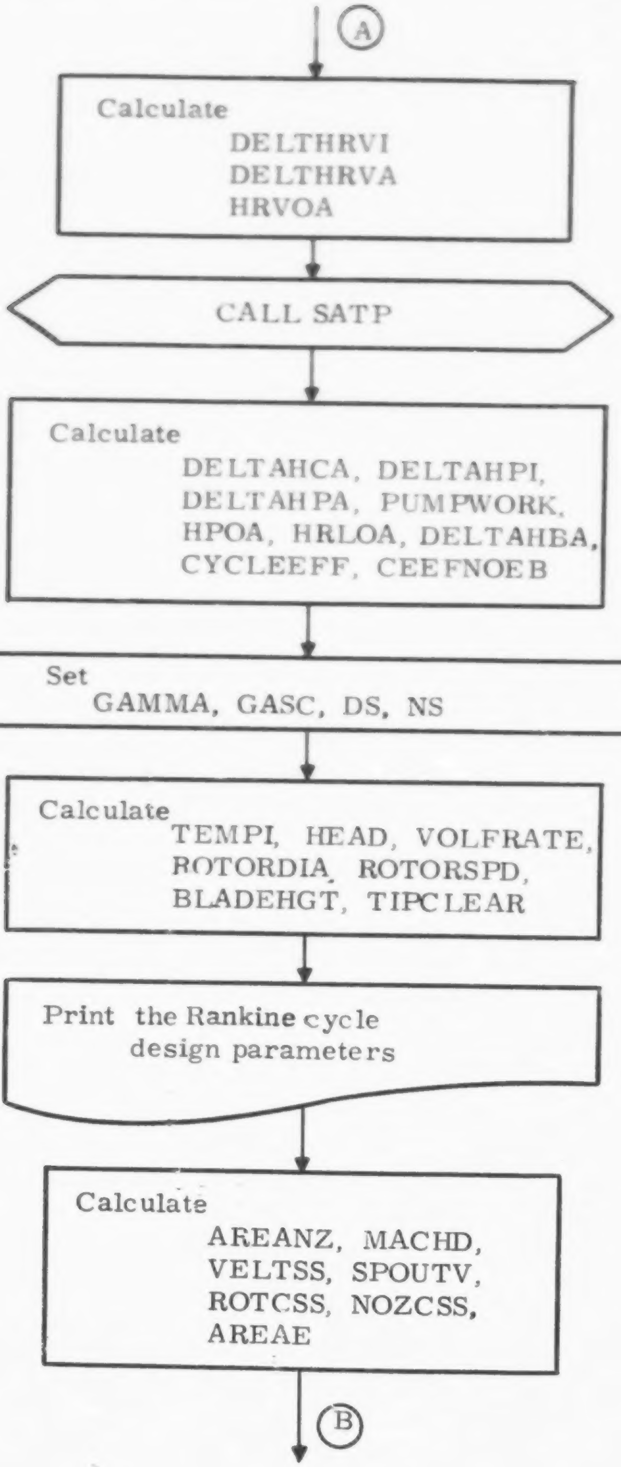
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
AREAE	Nozzle exit area	in^2
AREANZ	Nozzle throat area	in^2
BLADEHGT	Blade height	in.
CEFFNOEB	Cycle efficiency, not including EB	--
CYCLEEF	Cycle efficiency	--
MACHD	Design Mach Number	--
NOZCSS	Nozzle coefficient	--
ROTCSS	Rotor coefficient	--
ROTORDIA	Rotor diameter	ft
ROTORSP	Rotor speed	rpm
SPOUTV	Spouting velocity	ft/sec
TIPCLEA	Tip clearance	in.
VELTSS	Tip velocity	ft/sec

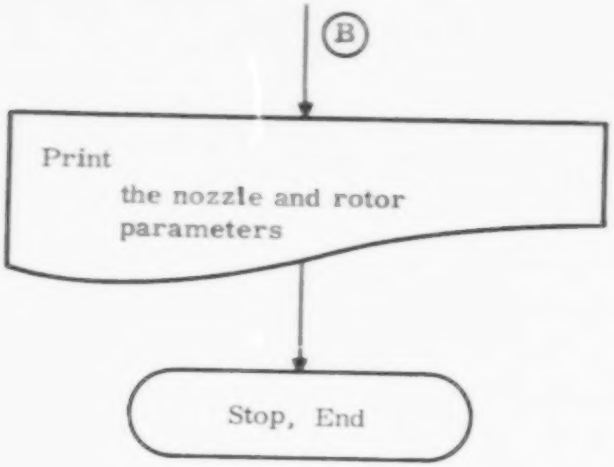
FLOW DIAGRAM -- TSIZE


Start
READ
ETTH, ETM, ER, EPTH,
EPM, EB, NOZANG, TBO
PBO, PC, HPT, NS
Is
NS = 0
?
NO
YES
CALL SUPP
STO = SBOV
CALL SATP
CALL SUPP
Calculate
DELTAHTI
DELTAHTA, FLOWRATE,
HTOA, TURBWORK
CALL SUPP
CALL SATP
A

FLOW DIAGRAM -- TSIZE (Cont'd)


A
Calculate
DELTHRVI
DELTHRVA
HRVOA
CALL SATP
Calculate
DELTAHCA, DELTAHPI,
DELTAHPA, PUMPWORK,
HPOA, HRLOA, DELTAHBA,
CYCLEEFF, CEEFNOEB
Set
GAMMA, GASC, DS, NS
Calculate
TEMPI, HEAD, VOLFRATE,
ROTORDIA, ROTORSPD,
BLADEHGT, TIPCLEAR
Print the Rankine cycle
design parameters
Calculate
AREANZ, MACHD,
VELTSS, SPOUTV,
ROTCSS, NOZCSS,
AREAE
B

FLOW DIAGRAM -- TSIZE (Cont'd)


B
Print
the nozzle and rotor parameters
Stop, End

PROGRAM LISTING -- TSIZE

```
*      THE PURPOSE OF THE PROGRAM IS TO FIND RANKINE CYCLE
*      EFFICIENCY, ROTOR DIAMETER, TURBINE BLADE HEIGHT, TIP
*      CLEARANCE, AND OTHER VARIABLES OF INTEREST FOR A
*      TURBINE DRIVEN AUTOMOBILE. STEADY-STATE CONDITIONS
*      ARE ASSUMED.
*
       COMMON NND,IND,NPSTEP,NTSTEP,NLINE,P(25),T(25),VLIQ(25),
+      VVAP(25),HLIQ(25),HVAP(25),PTAB(36),TTAB(20),VTAB(35,20),
+      HTAB(35,20),STAB(35,20)
       REAL MACHD, NOZCSS, NOZANG
       IND=1;NND=1
*      READ INPUT PARAMETERS
*      INPUT EFFICIENCY FACTORS
       READ: ETTH,ETM,EB,EPTH,EPM,ER,NOZANG
*      INPUT PRESSURE AND TEMPERATURE VALUES(CENTIGRADE AND
*      ATM) AND TURBINE HORSEPOWER
       READ: TBO,PBO,PC,HPT
       TBO=TBO*9/5+32.0
       PBO=PBO*14.7; PC=PC*14.7
*      FIND OUTPUT CONDITIONS AT OUTLET OF BOILER(INLET OF TURBINE)
*      NS=0, SATURATED VAPOR AT OUTLET OF BOILER
*      NS/=0, SUPERHEATED VAPOR AT OUTLET OF BOILER
       READ: NS
       IF (NS .NE. 0) GO TO 10; CALL SATP(TBO,PBO,VBOL,VBOV,HBOL,HB
+
+      OV,0)
       NND=NND+1
       GO TO 20
    10 CALL SUPP(PBO,TBO,HBOV,SBOV,VBOV,1)
       STO=SBOV
       IND=IND+1
    20 CONTINUE
*      FIND OUTPUT CONDITIONS AT OUTLET OF TURBINE(SUPERHEATED VAPO
*      R)
       CALL SUPP(PC,TTO,HTO,STO,VTO,2)
       IND=IND+1
       DELTAHTI=(HBOV-HTO); DELTAHTA=ETTH*DELTAHTI
       FLOWRATE=HPT/(ETM*DELTAHTA*3.92E-04); HTOA=HBOV-DELTAHTA
       TURBWORK=HPT/3.92E-04
       CALL SUPP(PC,TTO,HTOA,STO,VTO,3)
*      FIND OUTPUT CONDITIONS AT VAPOR SIDE OF REGENERATOR(SATURATE
*      D VAPOR)
       CALL SATP(PC,TCI,VRVOL,VRVOV,HRVOL,HRVOV,1)
       NND=NND+1
       DELTHRVI=(HTOA-HRVOV)
       DELTHRVA=ER*DELTHRVI;  HRVOA=HTOA-DELTHRVA
*      FIND OUTPUT CONDITIONS AT OUTLET OF CONDENSER(SATURATED LIQU
*      ID)
       CALL SATP(PC,TCO,VCOL,VCOV,HCOL,HCOV,1)
       DELTAHCA=(HRVOA-HCOL)
*      FIND OUTLET CONDITIONS AT OUTLET OF PUMP
       DELTAHPI= ((PBO-PC)*144.0*VCOL)/778.0
       DELTAHPA= DELTAHPI/EPTH
       PUMPWORK=(FLOWRATE*DELTAHPA)/EPM; HPP= PUMPWORK*3.92E-04
       HPOA=HCOL + DELTAHPA
*      FIND OUTPUT CONDITIONS AT OUTLET OF LIQUID SIDE OF
*      REGENERATOR
       HRLOA=HPOA+DELTHRVA
*      FIND THE HEAT INPUT AT THE BOILER
       DELTAHBA=(HBOV-HRLOA)/EB; BOILHEAT=FLOWRATE*DELTAHBA
```

PROGRAM LISTING -- TSIZE (Cont'd)

```
00610          CYCLEEFF=((TURBWORK-PUMPWORK)*100.)/BOILHEAT
00620          CEFFNOER=CYCLEEFF/ER
00630 *        CALCULATE VARIOUS TURBINE PARAMETERS
00640 *        ASSUME SPECIFIC HEAT AND RATIO OF SPECIFIC HEATS HAVE
00650 *        BEEN PREVIOUSLY CALCULATED. DS AND NS HAVE BEEN CHOSEN
00660 *        TO MAXIMIZE TURBINE EFFICIENCY.
00670          GAMMA=1.02; GASC=3.72; DS=1.3; NS=60
00680          TEMPI=THO+460.0
00690          HEAD=(GAMMA/(GAMMA-1.))*GASC*TEMPI*(1.-(PC/PBO)**((GAMMA-1.)
00700 +        /GAMMA))
00710          VOLFRATE=FLOWRATE*VTO/3600.
00720          ROTORDIA=(DS*(VOLFRATE)**.5)/HEAD**.25
00730          ROTORSPD=(NS*(HEAD)**.75)/VOLFRATE**.5
00740          BLADEHGT=.08*ROTORDIA*12.0
00750          TIPCLEAR=.02*BLADEHGT
00760          PRINT:"SUMMARY OF IMPORTANT RANKINE CYCLE TURBINE DESIGN PA"
00770 +        ,"RAMETERS"
00780          PRINT 1
00790          IF (NS.NE.0)  PRINT:"EXPANSION FROM SUPERSATURATED CONDITIO"
00800 +        ,"NS"
00810          IF (NS.EQ.0)  PRINT:"EXPANSION FROM SATURATED CONDITIONS"
00820          PRINT 1
00830          PRINT:"BOILER PRESSURE=",PBO,"PSIA   BOILER OUTLET TEMPERAT"
00840 +        ,"URE=",THO,"F"
00850          PRINT 1
00860          PRINT:"CONDENSER PRESSURE=",PC,"PSIA   TURBINE HORSEPOWER=",
00870 +        HPT
00880          PRINT1
00890          PRINT:"CYCLE EFFICIENCY=",CYCLEEFF,"   CYCLE EFFICIENCY(IDE"
00900 +        ,"AL BOILER)=",CEFFNOER
00910          PRINT1
00920          PRINT:"ROTOR DIAMETER=",ROTORDIA,"FT   ROTOR SPEED=",ROTORSP
00930 +        D,"RPM"
00940          PRINT1
00950          PRINT:"BLADE HEIGHT=",BLADEHGT,"IN   TIP CLEARANCE=",TIPCLEA
00960 +        R,"IN"
00970        1 FORMAT(1H0)
00980          AREANZ=(1./32.2**.5)*FLOWRATE*((TEMPI**.5)/PBO)*((GASC/GAMMA
00990 +        )**.5)*
01000 +        (1.+((GAMMA-1.)/2.)**((GAMMA+1.)/(2.*(GAMMA-1.))))*(1./3600)
01010          MACHD=(((PBO/PC)**((GAMMA-1.)/GAMMA)-1.)*(2./(GAMMA-1.)))**.
01020 +        5
01030          VELTSS=(ROTORSPD*6.28*ROTORDIA)/(2.*60.)
01040          SPOUTV=(2.*32.2*778.*DELTAHTI)**.5
01050          CV=SPOUTV*COS(NOZANG); CT=SPOUTV*SIN(NOZANG)
01060          C1=(CT*CT+(CV-VELTSS)*(CV-VELTSS))**.5
01070          ROTCSS=.99342-2.1698E-04*C1+7.5499E-08*(C1**2)
01080 +        -10.0874E-12*(C1**3)-9.5186E-16*(C1**4)+26.5401E-20*(C1**5)
01090          NOZCSS=((ETTH*SPOUTV)/(2.*VELTSS*(1.+ROTCSS))+(VELTSS/SPOUTV
01100 +        ))/COS(NOZANG)
01110          AREAE=AREANZ*(1./MACHD)*((2./(GAMMA+1.))*(1.+(MACHD**2)*
01120 +         ((GAMMA-1.)/2.)))**((GAMMA+1.)/(2.*(GAMMA-1.)))
01130          PRINT 1
01140          PRINT:"AREA NOZZLE THROAT=",AREANZ,"SQIN MACHSS=",MACHD; PRINT 1
01150          PRINT:"TIPVELSS=",VELTSS,"FT/SEC SPOUTVEL=",SPOUTV,"FT/SEC";
01160 +         PRINT 1
01170          PRINT:"ROTOR COEF SS=",ROTCSS,"  NOZZLE COEF SS=",NOZCSS
01180           PRINT 1
01190           PRINT:"AREA NOZZLE EXIT=",AREAE,"SQIN"
01200          STOP
01210          END
```

SUBROUTINE -- BLSIZ1

The subroutine BLSIZ1 calculates the length of vapor generator tubing required to raise the working fluid enthalpy from HFIN to HFOT. A cross-flow configuration is assumed, and the working fluid is single-phase. The working fluid flow rate and the combustor gas inlet temperature are specified; a number-of-transfer-units (NTU) calculation for the heat exchanger surface is employed.

Hydraulic diameters and flow areas are calculated in a subroutine GEOMCO. The COMMON of BLSIZ1 and GEOMCO must be identical for proper transfer of information. The tube length L (1) is iterated to an accuracy of 1%.

BLSIZ1 uses the following subroutines:

HT1PB
HTPF
HTGTB
HTGTF
HTGTM
HTTOC
HTTIC
HTGR
FCA

The subroutines HTTIC and HTTOC are blank; they have been included to allow for a water jacket in the tube walls. Appropriate heat transfer coefficient correlators can be used, if desirable, to construct these subroutines.

NOMENCLATURE -- BLSIZ1

FORTRAN Variables in COMMON:

There is no COMMON block in BLSIZ1.

FORTRAN Variables Input through READ Statements.*

FORTRAN Variable	Definition	Units
DCOIL	Coil diameter	in.
HFIN	Working fluid inlet enthalpy	Btu/lb
HFOT	Working fluid exit enthalpy	Btu/lb
L1	Initial guess tube length	ft
PPF	Working fluid pressure	psi

---

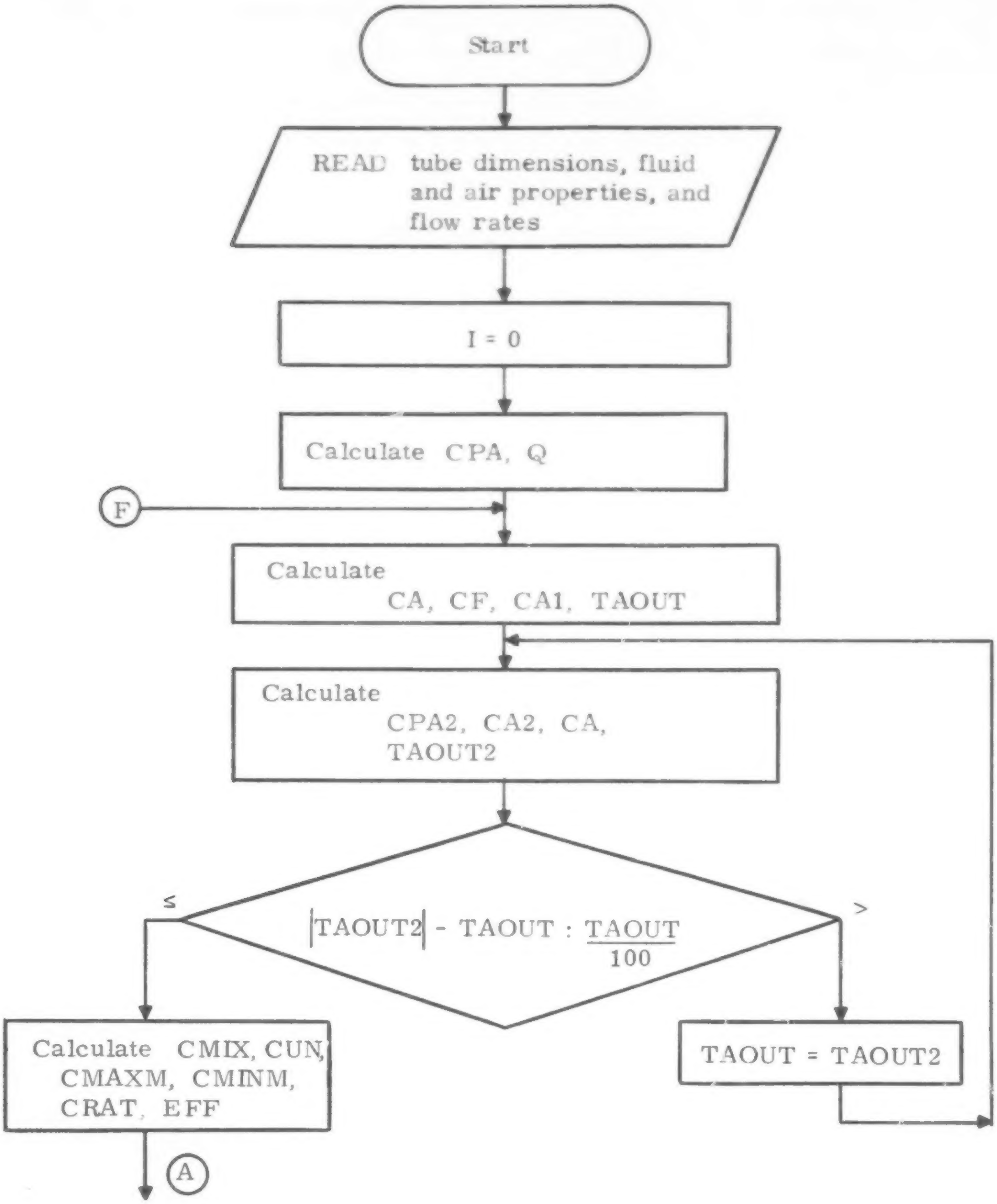
*See COMMON of MAINSYS for the remainder of these variables.

FORTRAN Variable	Definition	Units
TAIN	Inlet combustion gas temperature	°F
TFIN	Working fluid inlet temperature	°F
TFOT	Working fluid outlet temperature	°F
WA	Combustion gas flow rate	lb/hr
WA1	Reference gas flow rate	lb/hr
WF	Working fluid flow rate	lb/hr

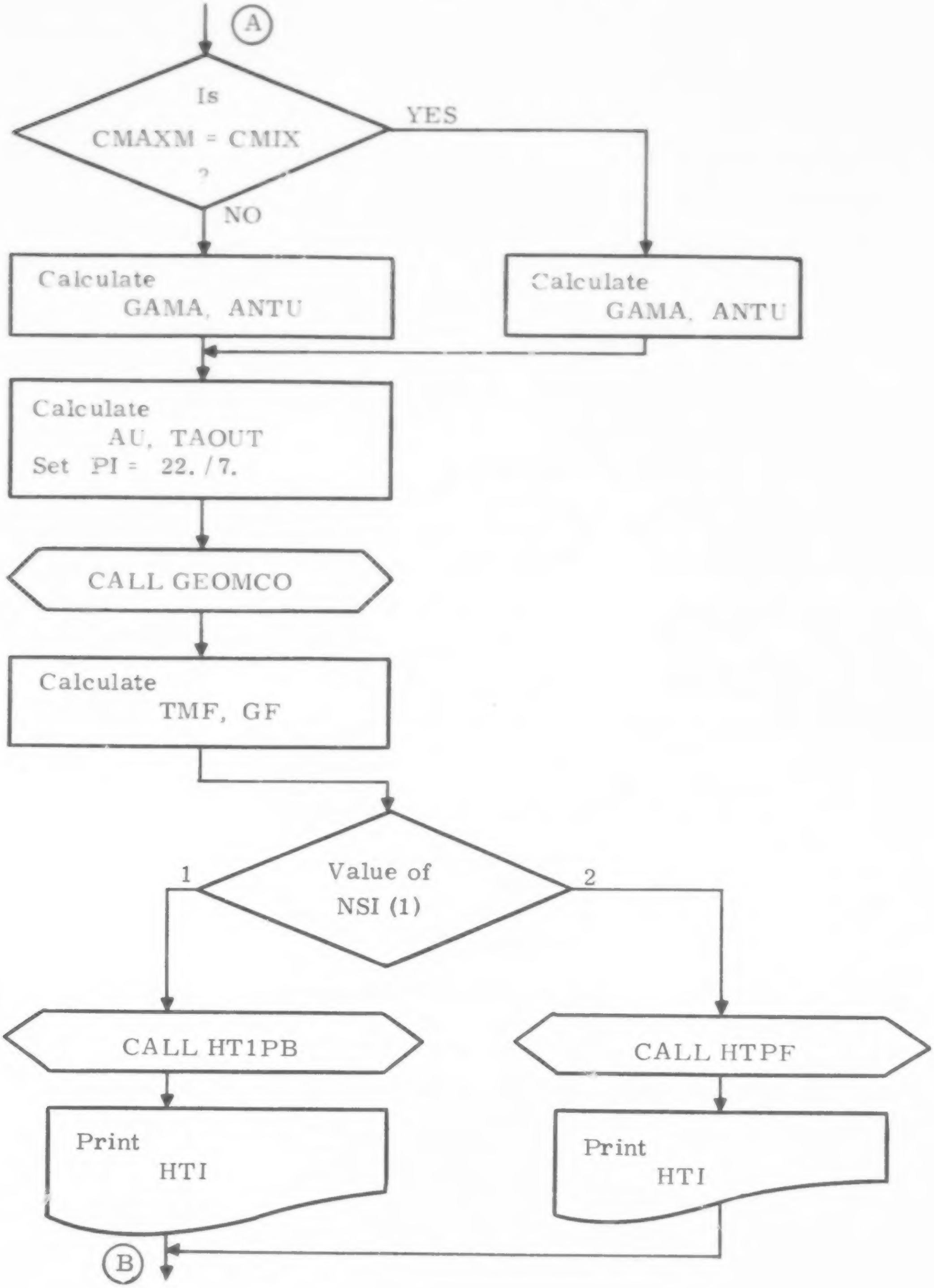
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
ANTU	Number of NTU's	--
CA	Heat capacity, combustion gas	Btu/hr °F
CF	Heat capacity, working fluid	Btu/hr °F
COILN	Number of coils	--
EFF	Heat exchanger effectiveness	--
HEIGHT	Coil height	in.
TAOUT	Outlet combustor gas temperature	°F
TMF	Mean working fluid temperature	°F
TUBEL	Tube length	in.

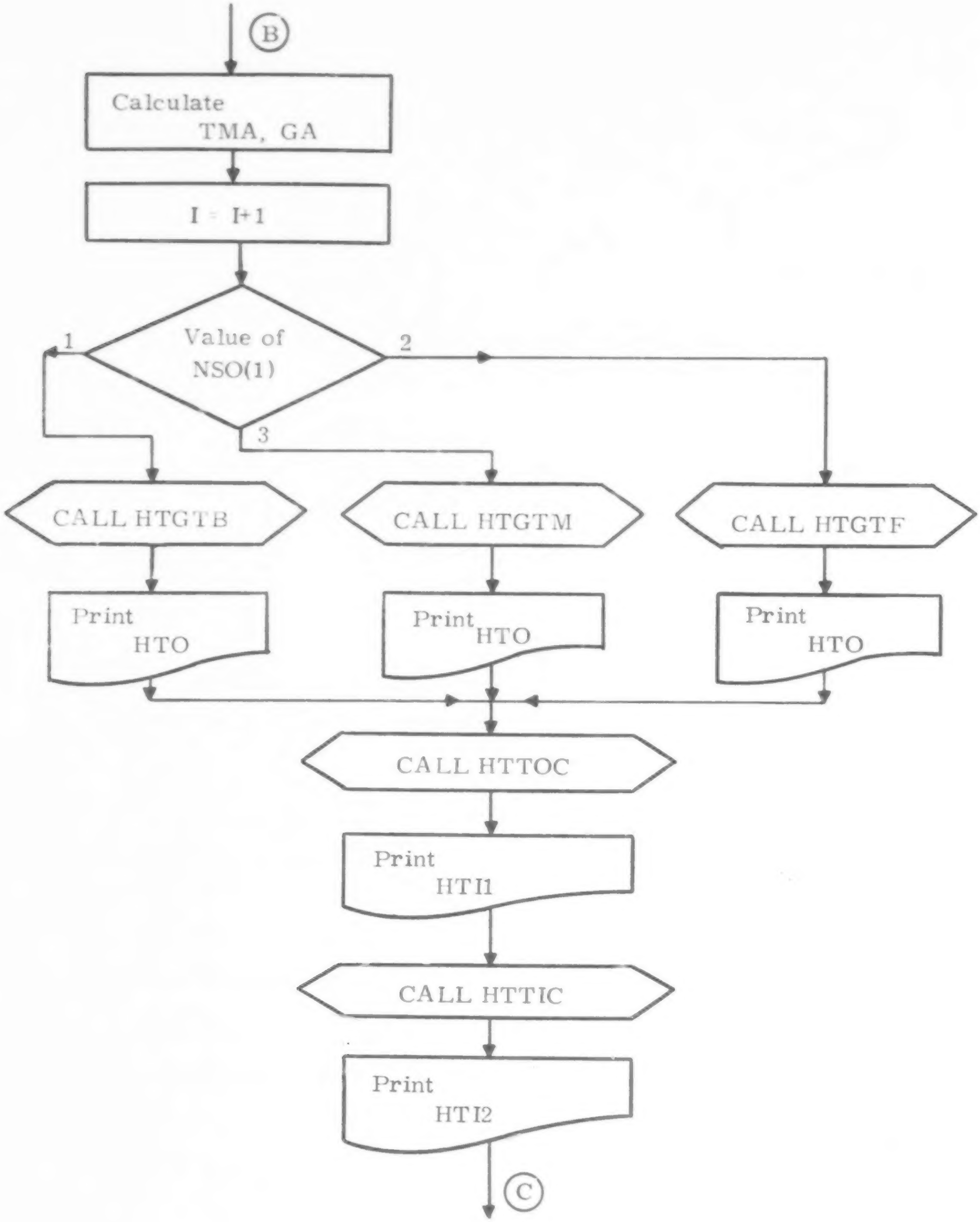
FLOW DIAGRAM -- BLSIZ1


Start
READ tube dimensions, fluid and air properties, and flow rates
I = 0
Calculate CPA, Q
F
Calculate CA, CF, CA1, TAOUT
Calculate CPA2, CA2, CA, TAOUT2
|TAOUT2 - TAOUT| : TAOUT/100
≤
>
Calculate CMIX, CUN, CMAXM, CMINM, CRAT, EFF
TAOUT = TAOUT2
A

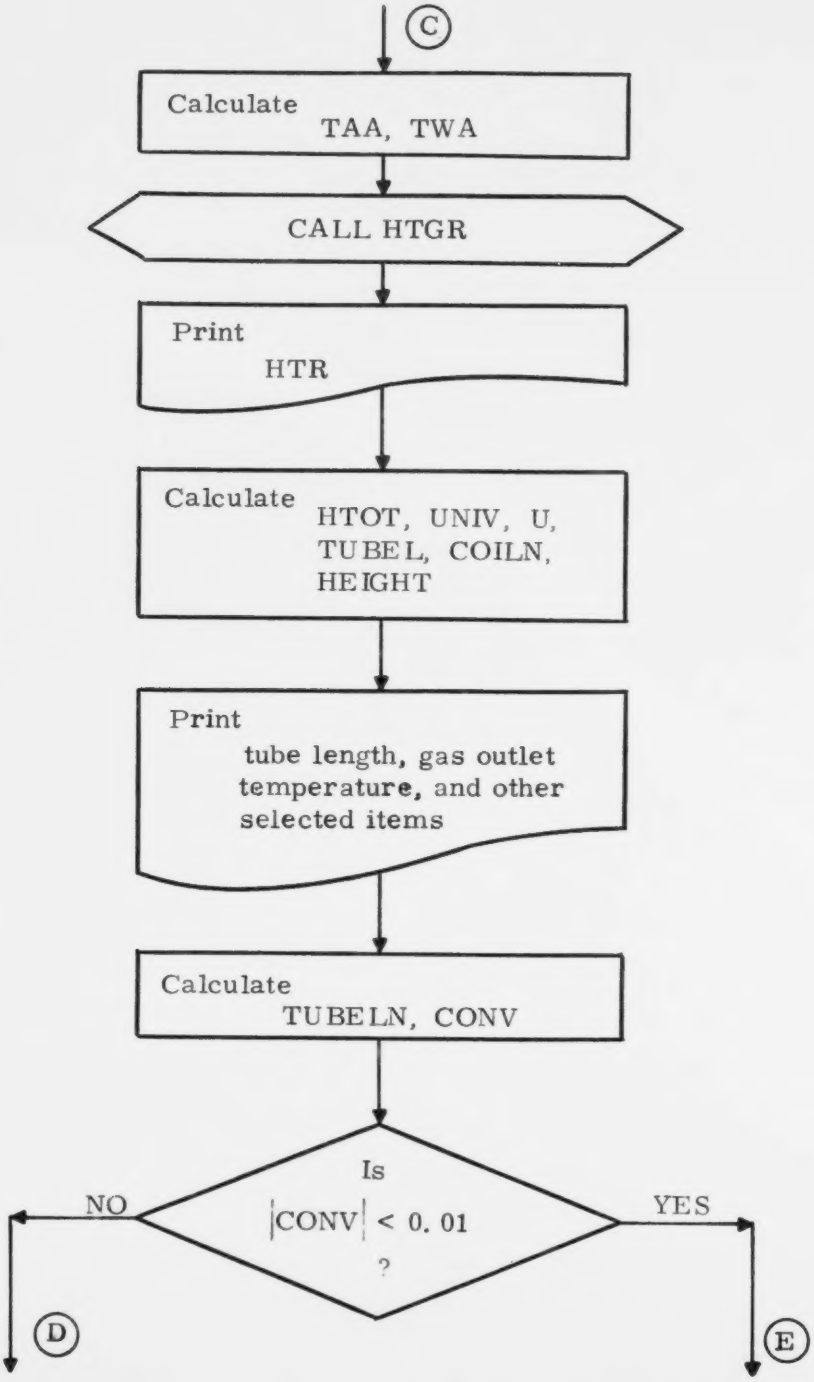
FLOW DIAGRAM -- BLSIZ1 (Cont'd)


A
Is CMAXM = CMIX ?
YES
NO
Calculate GAMA, ANTU
Calculate GAMA, ANTU
Calculate AU, TAOUT
Set PI = 22./7.
CALL GEOMCO
Calculate TMF, GF
Value of NSI (1)
1
2
CALL HT1PB
CALL HTPF
Print HTI
Print HTI
B

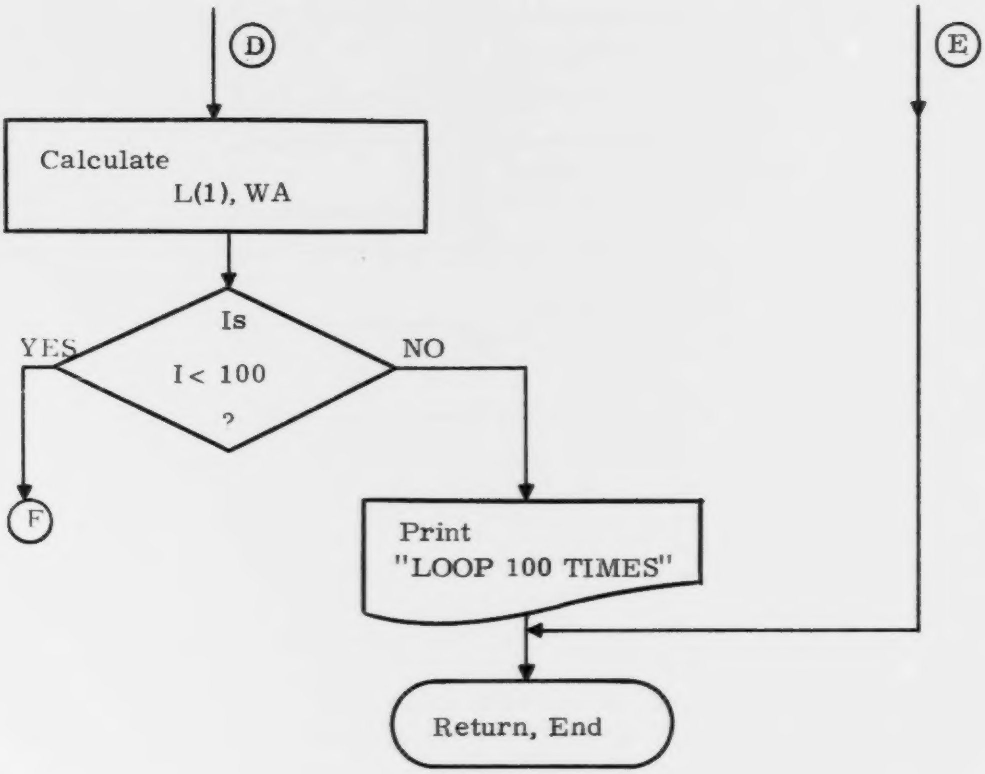
FLOW DIAGRAM -- BLSIZ1 (Cont'd)


B
Calculate TMA, GA
I = I+1
Value of NSO(1)
1
2
3
CALL HTGTB
CALL HTGTM
CALL HTGTF
Print HTO
Print HTO
Print HTO
CALL HTTOC
Print HTI1
CALL HTTIC
Print HTI2
C

FLOW DIAGRAM -- BLSIZ1 (Cont'd)


C
Calculate TAA, TWA
CALL HTGR
Print HTR
Calculate HTOT, UNIV, U, TUBEL, COILN, HEIGHT
Print tube length, gas outlet temperature, and other selected items
Calculate TUBELN, CONV
Is |CONV| < 0. 01 ?
NO
YES
D
E

FLOW DIAGRAM -- BLSIZ1 (Cont'd)


D
E
Calculate L(1), WA
Is I< 100 ?
YES
NO
F
Print "LOOP 100 TIMES"
Return, End

PROGRAM LISTING -- BLSIZ1

```
      SUBROUTINE BLSIZ1
*     SINGLE PHASE FLUID
*     CROSS FLOW
      REAL   L,WPCYL
      REAL L1
      READ(21,200)LINE,DO(1),DI(1),NSO(1),NSI(1),X2L(1)
 100  FORMAT(I6,5F10.4)
      READ(21,100)LINE,FNO(1),FHO(1),FTO(1)
      READ(21,100)LINE,FNI(1),FHI(1),FTI(1)
      READ(21,100)LINE,DS(1),BH(1),BT(1)
      READ(21,100)LINE,DCOIL,WA,TAIN
 200  FORMAT(I6,2F10.4,2I10,F10.4)
      READ(21,100)LINE,WF,TFIN,TFOT,HFIN,HFOT
      READ(21,100)LINE,PPF
      READ(21,250)LINE,NM(1),NMO(1),NMI(1)
      READ(21,100)LINE,RM(1),L(1),WA1,L1
      I=0
 250  FORMAT(I6,3I10)
      CPA=FCA(TAIN)
      Q=WF*(HFOT-HFIN)
  56  CA=WA*CPA
      CA1=CA
      CF=Q/(TFOT-TFIN)
      TAOUT=TAIN-(Q/CA)
 280  CPA2=FCA(TAOUT)
      CA2=WA*CPA2
      CA=(CA1+CA2)/2.
      TAOUT2=TAIN-(Q/CA)
      IF(ABS(TAOUT2-TAOUT)-TAOUT/100.)270,270,260
 260  TAOUT=TAOUT2
      GO TO 280
 270  CONTINUE
      CMIX=CA
      CUN=CF
      CMAXM=AMAX1(CA,CF)
      CMINM=AMIN1(CA,CF)
      CRAT=CMAXM/CMINM
      EFF=Q/(CMINM*(TAIN-TFIN))
      IF(CMAXM.EQ.CMIX) GO TO 15
      GAMA=-(ALOG(1.-EFF))/CRAT
      ANTU=-(ALOG(1.-GAMA))*CRAT
      GO TO 20
  15  CONTINUE
      GAMA=-(ALOG(1.-(EFF/CRAT)))*CRAT
      ANTU=-(ALOG(1.-GAMA))
  20  CONTINUE
      AU=ANTU*CMINM
      TAOUT=TAIN-(Q/CA)
      PI=22./7.
      CALL GEOMCO(1)
*     FLUID SIDE
      TMF=(TFIN+TFOT)/2.
      GF=WF/(ACI(1))
      MI=NSI(1)
      GO TO (30,40),MI
  30  CONTINUE
      CALL HT1PH(HTI,1,GF,PPF,TMF)
      WRITE(6,35)HTI
  35  FORMAT (8H HT1PH  ,E15.5)
      GO TO 50
```

PROGRAM LISTING -- BLSIZ1 (Cont'd)

```
  40   CONTINUE
       CALL HTPF(HTI,1,GF,FPF,TMF,DD,DD,DD,DD,DD,DD)
       WRITE(6,45)HTI
  45   FORMAT (7H HTPF  ,E15.5)
  50   CONTINUE
*      AIR SIDE
       TMA=(TAIN+TAOUT)/2.
  55   GA=WA/(ACO(1)*L(1)*12.)
       I=I+1
       MI=NSO(1)
       GO TO (60,70,80),MI
  60   CONTINUE
       CALL HTGTB(HTO,1,GA,TMA)
       WRITE(6,65)HTO
  65   FORMAT(8H HTGTB  ,E15.5)
       GO TO 90
  70   CONTINUE
       CALL HTGTF(HTO,1,GA,TMA)
       WRITE(6,75)HTO
  75   FORMAT (8H HTGTF  ,E15.5)
       GO TO 90
  80   CONTINUE
       CALL HTGTM(HTO,1,GA,TMA)
       WRITE(6,85)HTO
  85   FORMAT (8H HTGTM  ,E15.5)
  90   CONTINUE
       CALL HTIOC(HTI1,TMA)
       WRITE(6,95)HTI1
  95   FORMAT (8H HTIOC  ,E15.5)
       CALL HTIIC(HTI2,TMA)
       WRITE (6,96)HTI2
  96   FORMAT (8H HTIIC  ,E15.5)
*      RADIATION
       TAA=TMA
       TWA=(TMA+TMF)/2.
       CALL HTGR(HTR,TAA,TWA)
       WRITE (6,97)HTR
  97   FORMAT(7H HTGR  ,E15.5)
       HTOT=HTO+HTR
       UINV=(1./(HTI*(DI(1)/DO(1))))+(1./HTOT)+(1./HTI1)
      1     +(1./(HTI2*(DI(1)/DO(1))))
       U=1./UINV
       TUBEL=AU*UINV/(PI*DO(1))
       COILN=TUBEL/(PI*DCOIL)
       HEIGHT=(COILN*DO(1)+(COILN-1.)*X2L(1))/12.
       WRITE(6,300)CA,CF,FFF
 300   FORMAT (13H CA,CF,FFF   ,3E15.5)
       WRITE(6,301)ANTU,AU,TAOUT
 301   FORMAT (17H ANTU,AU,TAOUT   ,3E15.5)
       WRITE(6,302)TMF,GF,HTI
 302   FORMAT (14H TMF,GF,HTI   ,3E15.5)
       WRITE(6,303)TMA,GA,HTO
 303   FORMAT (14H TMA,GA,HTO   ,3E15.5)
       WRITE(6,304)HTI1,HTI2,HTR
 304   FORMAT (17H HTI1,HTI2,HTR   ,3E15.5)
       WRITE(6,305)U,UINV
 305   FORMAT (10H U,UINV   ,2E15.5)
       WRITE(6,306)TUBEL
 306   FORMAT (9H TUBEL   ,E15.5)
       WRITE(6,307)COILN
```

PROGRAM LISTING -- BLSIZ1 (Cont'd)

```
 307  FORMAT (9H COILN    ,E15.5)
      WRITE(6,308)HEIGHT
 308  FORMAT (10H HEIGHT    ,E15.5)
      TUBELN=TUBEL/12.
      CONV=(TUBELN-L(1))/TUBELN
      IF(ABS(CONV).LT.0.01) GO TO 310
      L(1)=L(1)-(L(1)-TUBELN)*.5
      WA=WA1*L(1)/L1
      IF(I.LT.100) GO TO 56
      WRITE(6,311)
 311  FORMAT(15H LOOP 100 TIMES)
 310  RETURN
      END
```

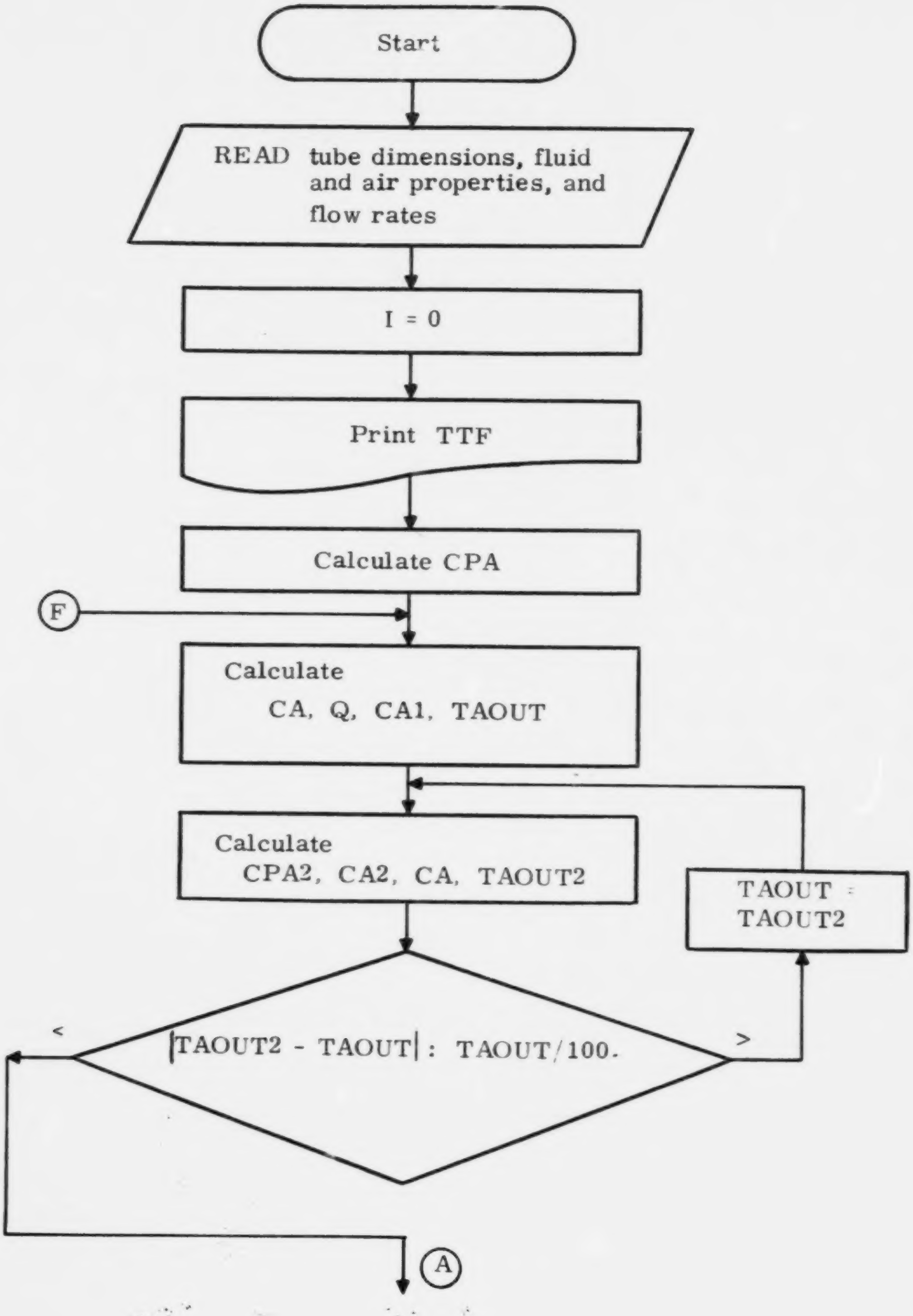
SUBROUTINE BLSIZ2

Subroutine BLSIZ2 is similar to BLSIZ1 except that the working fluid is two-phase. Refer to the section on BLSIZ1 for details.

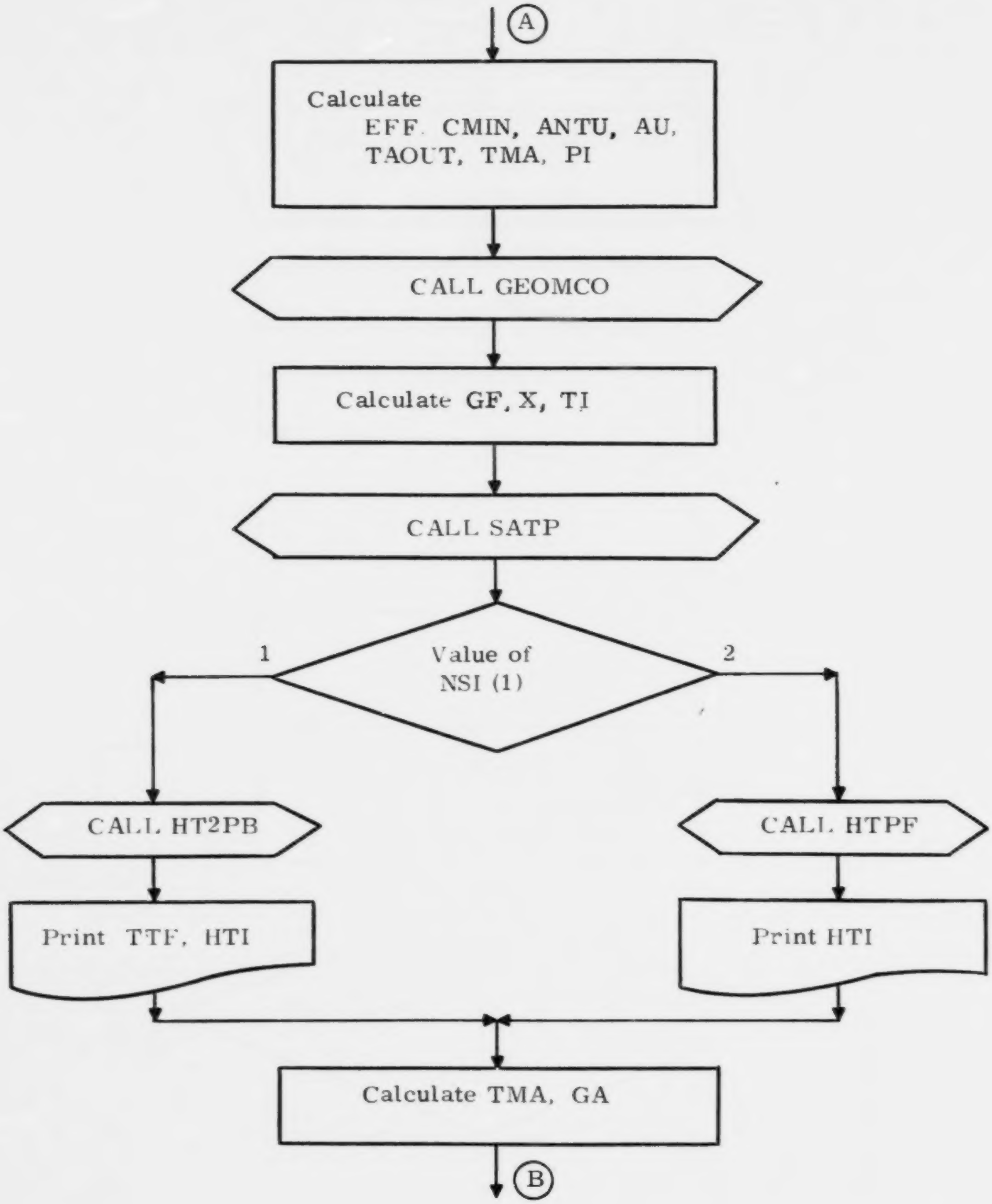
BLSIZ2 uses the following subroutines:

- FCA
- GEOMCO
- SATP
- HT2PB
- HTPF
- HTGTB
- HTGTF
- HTGTM
- HTTOC
- HTTIC
- HTGR

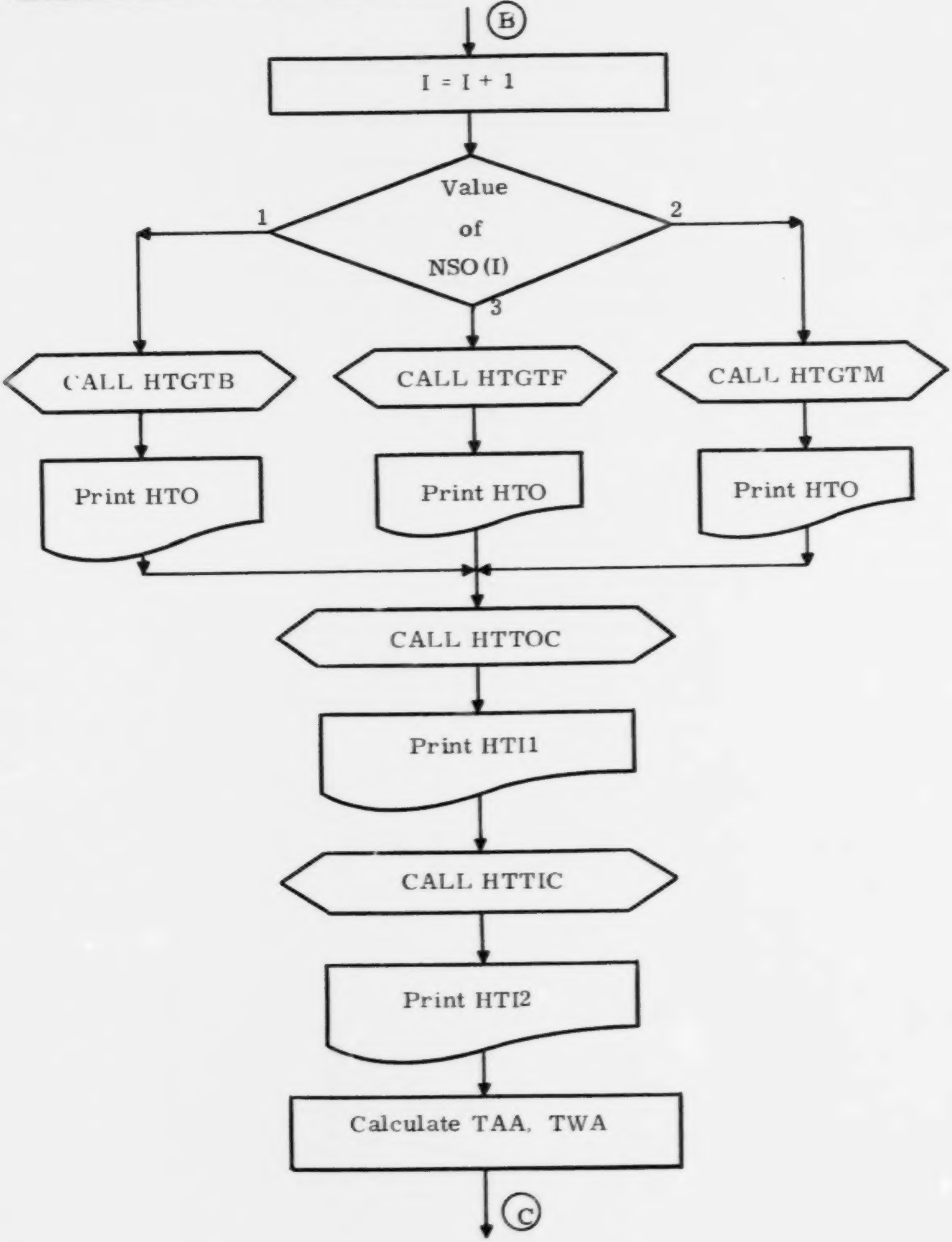
FLOW DIAGRAM -- BLSIZ2


Start
READ tube dimensions, fluid and air properties, and flow rates
I = 0
Print TTF
Calculate CPA
F
Calculate CA, Q, CA1, TAOUT
Calculate CPA2, CA2, CA, TAOUT2
TAOUT = TAOUT2
|TAOUT2 - TAOUT| : TAOUT/100.
<
>
A

FLOW DIAGRAM -- BLSIZ2 (Cont'd)

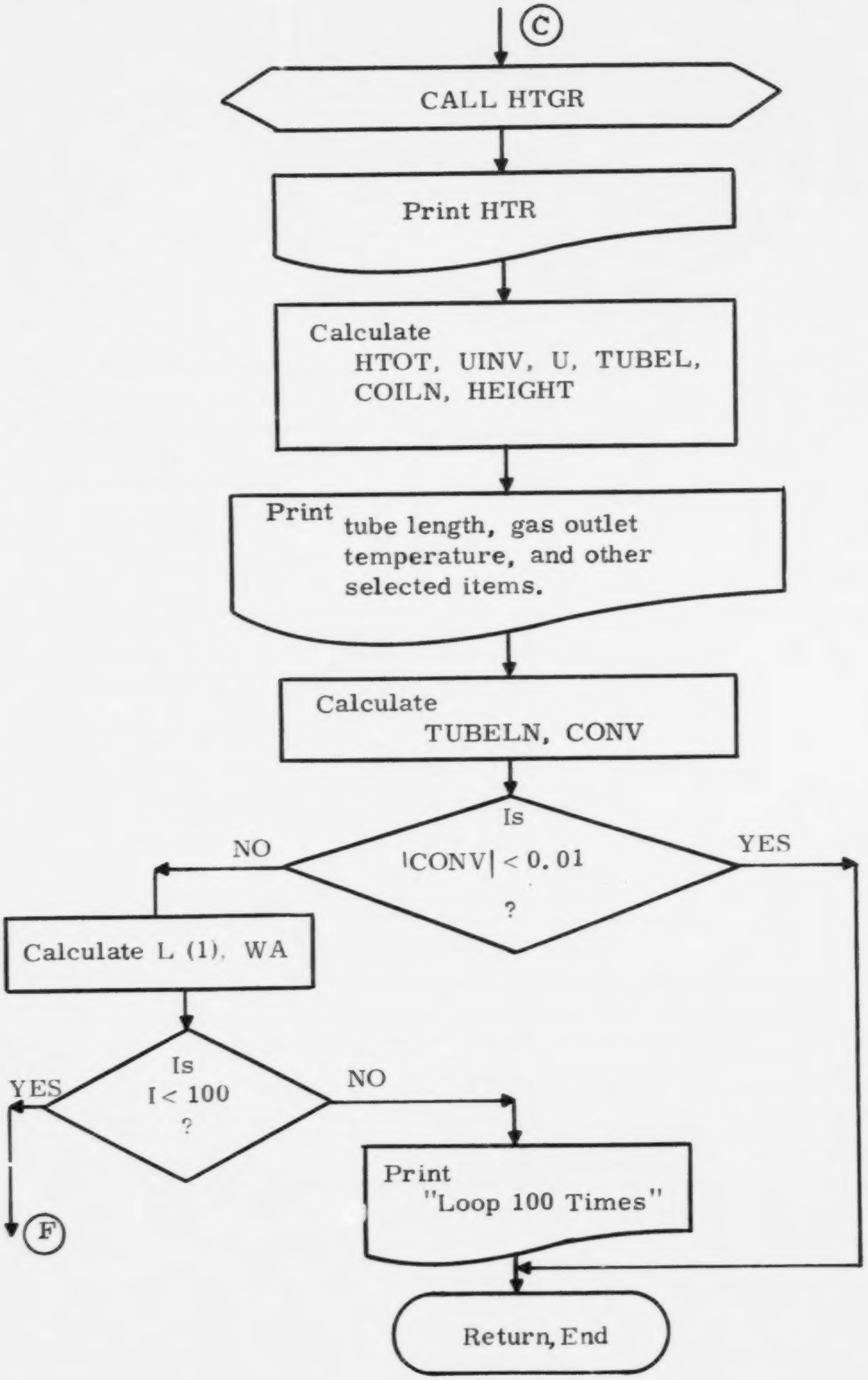

A
Calculate
EFF. CMIN, ANTU, AU,
TAOUT, TMA, PI
CALL GEOMCO
Calculate GF, X, TI
CALL SATP
Value of
NSI (1)
1
2
CALL HT2PB
CALL HTPF
Print TTF, HTI
Print HTI
Calculate TMA, GA
B

FLOW DIAGRAM -- BLSIZ2 (Cont'd)



B
I = I + 1
Value of NSO (I)
1
2
3
CALL HTGTB
CALL HTGTF
CALL HTGTM
Print HTO
Print HTO
Print HTO
CALL HTTOC
Print HTI1
CALL HTTIC
Print HTI2
Calculate TAA, TWA
C

FLOW DIAGRAM -- BLSIZ2 (Cont'd)



C
CALL HTGR
Print HTR
Calculate HTOT, UINV, U, TUBEL, COILN, HEIGHT
Print tube length, gas outlet temperature, and other selected items.
Calculate TUBELN, CONV
Is |CONV| < 0.01 ?
NO
YES
Calculate L (1), WA
Is I < 100 ?
YES
NO
F
Print "Loop 100 Times"
Return, End

<u>PROGRAM LISTING -- BLSIZ2</u>

```
      SUBROUTINE BLSIZ2
*     TWO PHASE FLUID
*     CROSS FLOW
      REAL   L,NPCYL
      REAL L1
      READ(22,100)LINE,DO(1),DI(1),NSO(1),NSI(1),X2L(1)
      READ(22,200)LINE,FNO(1),FHO(1),FTO(1)
      READ(22,200)LINE,FNI(1),FHI(1),FTI(1)
      READ(22,200)LINE,DS(1),BH(1),BT(1)
      READ(22,200)LINE,DCOIL,WA,TAIN
      READ(22,200)LINE,WF,XIN,XOUT,HFG,TTF
      READ(22,250)LINE,NM(1),NMO(1),NMI(1)
      READ(22,200)LINE,RM(1),L(1),WA1,L1
      I=0
      WRITE(6,20)TTF
  20  FORMAT (6H TTF  ,E15.5)
      CPA=FCA(TAIN)
  56  CA=WA*CPA
      Q=WF*(XOUT-XIN)*HFG
      CA1=CA
      TAOUT=TAIN-(Q/CA)
 280  CPA2=FCA(TAOUT)
      CA2=WA*CPA2
      CA=(CA1+CA2)/2.
      TAOUT2=TAIN-(Q/CA)
      IF(ABS(TAOUT2-TAOUT)-TAOUT/100.)270,270,260
 260  TAOUT=TAOUT2
      GO TO 280
 270  CONTINUE
      EFF=Q/(CA*(TAIN-TTF))
      CMIN=CA
      ANTU=-ALOG(1.-EFF)
      AU=ANTU*CMIN
      TAOUT=TAIN-(Q/CA)
      TMA=(TAIN+TAOUT)/2.
      PI=22./7.
      CALL GEOMCO(1)
*     FLUID SIDE
      GF=WF/(ACI(1))
      X=(XIN+XOUT)/2.
      TI=(TMA+TTF)/2.
      WRITE(6,24)TI
  24  FORMAT (5H TI  ,E15.5)
      CALL SATP(PPF,TTF,DFL,DFV,HFL,HFV,0)
      WRITE(6,25)T(128)
  25  FORMAT(9H T(128)  ,E15.5)
      MI=NSI(1)
      GO TO(30,40),MI
  30  CONTINUE
      CALL HT2PH(HTI,1,GF,TTF,TI,X,PPF,DFL,DFV,HFL,HFV)
      WRITE(6,31)TTF
  31  FORMAT(6H TTF  ,E15.5)
      WRITE(6,35)HTI
  35  FORMAT (8H HT2PH  ,E15.5)
      GO TO 50
  40  CONTINUE
      CALL HTPF(HTI,1,GF,PPF,TTF,TI,X,DFL,DFV,HFL,HFV)
      WRITE (6,45)HTI
  45  FORMAT (7H HTPF  ,E15.5)
```

PROGRAM LISTING -- BLSIZ2 (Cont'd)

```
  50  CONTINUE
*     AIRSIDE
      TMA=(TAIN*TAOUT)/2.
      GA=WA/(ACO(1)*L(1)*12.)
      I=I+1
      MI=NSO(1)
      GO TO(60,70,80),MI
  60  CONTINUE
      CALL HTGTR(HTO,1,GA,TMA)
      WRITE(6,65)HTO
  65  FORMAT (8H HTGTB  ,E15.5)
      GO TO 90
  70  CONTINUE
      CALL HTGTF(HTO,1,GA,TMA)
      WRITE (6,75)HTO
  75  FORMAT (8H HTGTF  ,E15.5)
      GO TO 90
  80  CONTINUE
      CALL HTGTM(HTO,1,GA,TMA)
      WRITE (6,85)HTO
  85  FORMAT (8H HTGTM  ,E15.5)
  90  CONTINUE
      CALL HTTOC(HTI1,TMA)
      WRITE (6,95)HTI1
  95  FORMAT (8H HTTOC  ,E15.5)
      CALL HTTIC(HTI2,TMA)
      WRITE (6,96)HTI2
  96  FORMAT (8H HTTIC  ,E15.5)
*     RADIATION
      TAA=TMA
      TWA=(TMA+TTF)/2.
      CALL HTGR(HTR,TAA,TWA)
      WRITE (6,97)HTR
  97  FORMAT (7H HTGR  ,E15.5)
      HTOT=HTO+HTR
      UINV=(1./(HTI*(DI(1)/DO(1))))+(1./HTOT)+(1./HTI1)
     1    +(1./(HTI2*(DI(1)/DO(1))))
      U=1./UINV
      TUBEL=AU*UINV/(PI*DO(1))
      COILN=TUBEL/(PI*DCOIL)
      HEIGHT=(COILN*DO(1)+(COILN-1.)*X2L(1))/12.
      WRITE(6,300)CA,EFF
 300  FORMAT(10H CA,EFF   ,2E15.5)
      WRITE(6,301)ANTU,AU,TAOUT
 301  FORMAT (17H ANTU,AU,TAOUT   ,3E15.5)
      WRITE(6,302)GF,HTI
 302  FORMAT(10H GF,HTI   2E15.5)
      WRITE(6,303)TMA,GA,HTO
 303  FORMAT (14H TMA,GA,HTO   ,3E15.5)
      WRITE(6,304)HTI1,HTI2,HTR
 304  FORMAT (17H HTI1,HTI2,HTR   ,3E15.5)
      WRITE(6,305)U,UINV
 305  FORMAT (10H U,UINV   ,2E15.5)
      WRITE(6,306)TUBEL
 306  FORMAT (9H TUBEL   ,E15.5)
      WRITE(6,307) COILN
```

PROGRAM LISTING -- BLSIZ2 (Cont'd)

```
 307  FORMAT(8H COILN  ,E15.5)                                   01110
      WRITE(6,308)HEIGHT                                         01120
 308  FORMAT (10H HEIGHT   ,E15.5)                               01130
 100  FORMAT (I6,2F10.4,2I10,F10.4)                              01140
 200  FORMAT(I6,5F10.4)                                          01150
 250  FORMAT(I6,3I10)                                            01155
      TUBELN=TUBEL/12.                                           01156
      CONV=(TUBELN-L(1))/TUBELN                                  01157
      IF(ABS(CONV).LT.0.01) GO TO 310                            01158
      L(1)=L(1)-(L(1)-TUBELN)*.5                                 01159
      WA=WA1*L(1)/L1                                             01160
      IF(I.LT.100) GO TO 56                                      01161
      WRITE(6,311)                                               01162
 311  FORMAT(15H LOOP 100 TIMES)                                 01163
 311  FORMAT(15H LOOP 100 TIMES)                                 01163
 310  RETURN                                                     01164
      END                                                        01170
```

SUBROUTINE CONDSZ

The subroutine CONDSZ calculates the condenser size required to condense the working fluid. The condensing temperature and flow rate and the air temperature and flow rate are input and a NTU calculation is carried out for a particular heat exchanger design. A cross-flow configuration is assumed.

CONDSZ uses the following subroutines:

SATP
FCA
GEOMC2
HT2PC
HTAC

The subroutine GEOMC2 is similar to GEOMCO, and calculates hydraulic diameters and flow areas. The COMMON for CONDSZ must be consistent with the COMMON's for all the subroutines employed.

The present subroutine is written for a louvered fin on a flattened tube heat exchanger.

NOMENCLATURE -- CONDSZ

FORTRAN Variables in COMMON:

There is no COMMON block in CONDSZ.

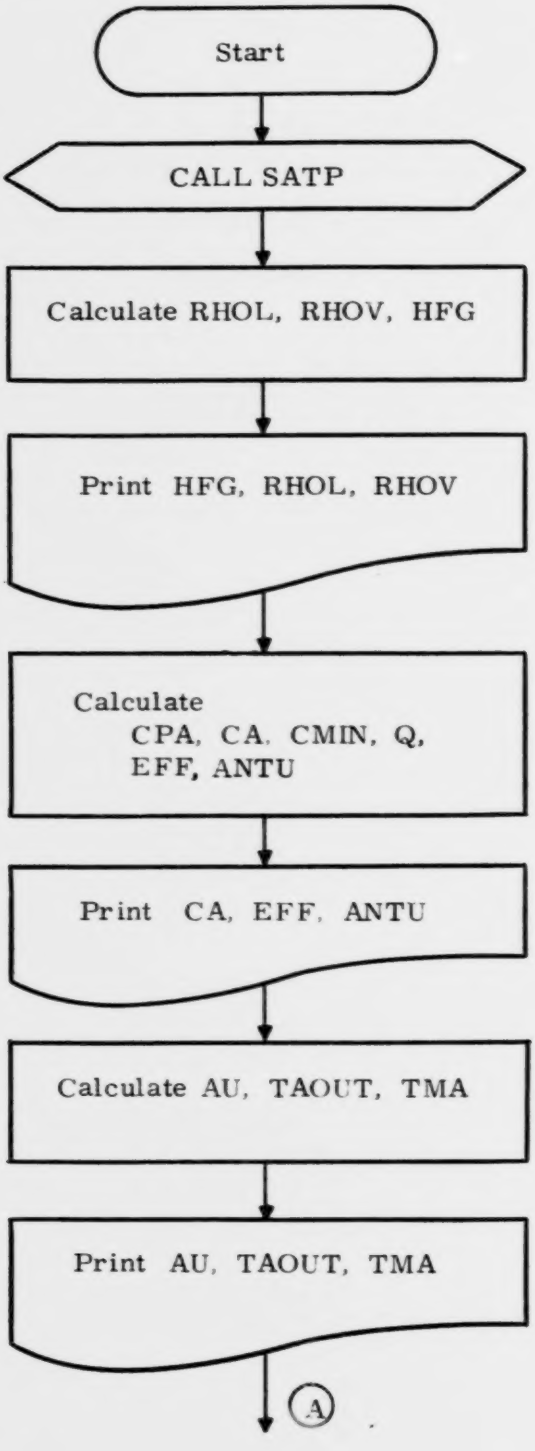
FORTRAN Variables in Argument List:

FORTRAN Variable	Definition	Units
TAIN	Inlet air temperature	°F
TTF	Condensing temperature	°F
WA	Air flow rate	lb/hr
WF	Working fluid flow rate	lb/hr
X	Average quality	--
XIN	Inlet quality	--
XOUT	Outlet quality	--

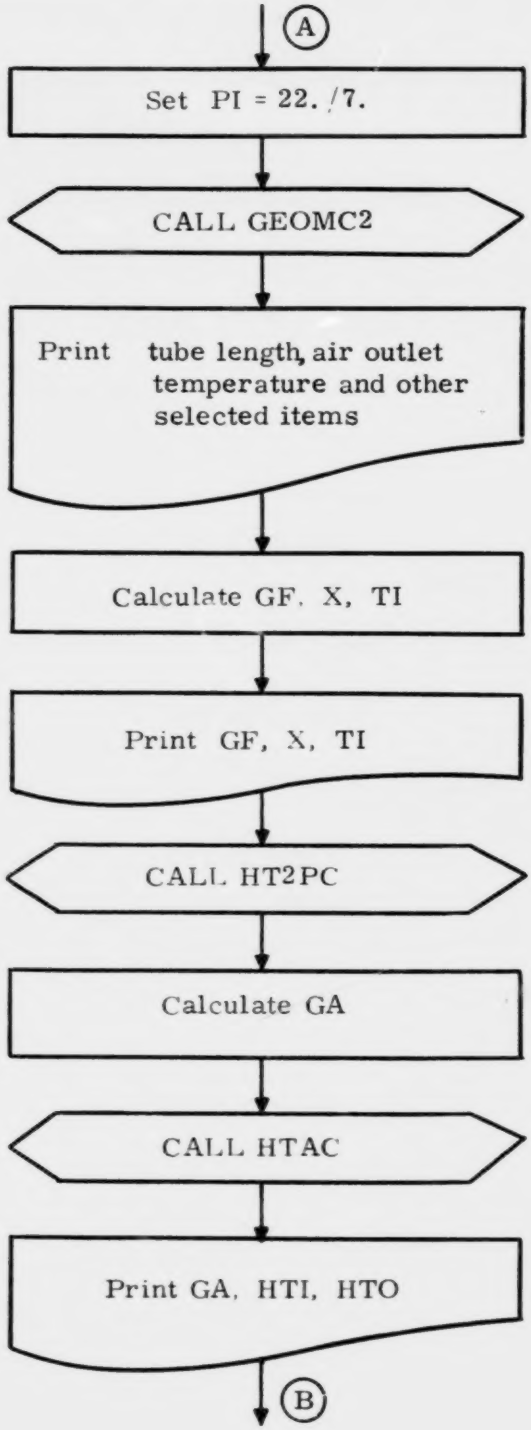
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
ANTU	Number of NTU's	--
CA	Air heat capacity	Btu/hr
EFF	Heat exchanger effectiveness	--
SECTNS	Number of flowpasses	--
TAOUT	Outlet air temperature	°F
THCO	Tube height	in.
TUBEL	Tube length	in.
TUBNC	Number of condenser tubes	--
WCO	Tube width	in.
WCOND	Frontal width	in.

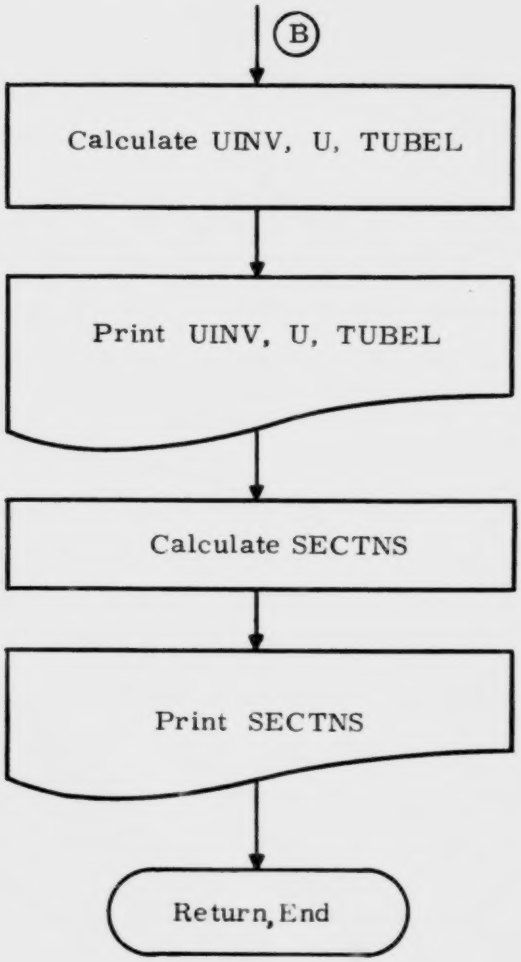
FLOW DIAGRAM -- CONDSZ


Start
CALL SATP
Calculate RHOL, RHOV, HFG
Print HFG, RHOL, RHOV
Calculate
CPA, CA, CMIN, Q,
EFF, ANTU
Print CA, EFF, ANTU
Calculate AU, TAOUT, TMA
Print AU, TAOUT, TMA
A

FLOW DIAGRAM -- CONDSZ (Cont'd)


A
Set PI = 22./7.
CALL GEOMC2
Print tube length, air outlet temperature and other selected items
Calculate GF, X, TI
Print GF, X, TI
CALL HT2PC
Calculate GA
CALL HTAC
Print GA, HTI, HTO
B

FLOW DIAGRAM -- CONDSZ (Cont'd)


B
Calculate UINV, U, TUBEL
Print UINV, U, TUBEL
Calculate SECTNS
Print SECTNS
Return, End

PROGRAM LISTING -- CONDSZ

```
      SUBROUTINE CONDSZ(TIF,X,WA,WF,XOUT,XIN,TAIN)
*     CONDENSER SIZING
*     CROSS FLOW
      REAL    L,NPCYL
      CALL SATP(PPF,TIF,VL,VV,HFL,HFV,0)
      RHOL=1./VL
      RHOV=1./VV
      HFG=HFV-HFL
      WRITE(6,50)HFG
   50 FORMAT (6H HFG  ,E15.5)
      WRITE(6,60)RHOL,RHOV
   60 FORMAT (12H RHOL,RHOV  ,2E15.5)
      CPA=FCA(TAIN)
      CA=WA*CPA
      CMIN=CA
      Q=WF*(XIN-XOUT)*HFG
      EFF=Q/(CMIN*(TIF-TAIN))
      ANTU=-ALOG(1.-EFF)
      WRITE(6,100)CA,EFF,ANTU
  100 FORMAT(14H CA,EFF,ANTU  ,3E15.5)
      AU=ANTU*CMIN
      TAOUT=TAIN+(Q/CA)
      TMA=(TAIN+TAOUT)/2.
      WRITE(6,110)AU,TAOUT,TMA
  110 FORMAT (15H AU,TAOUT,TMA  ,3E15.5)
      PI=22./7.
      CALL GEOMC2(4)
      WRITE(6,120)ACO(4),DHO(4)
  120 FORMAT(16H ACO(4),DHO(4)  ,2E15.5)
      WRITE(6,130)ACI(4),DHI(4),TUBNC
  130 FORMAT (22H ACI(4),DHI(4),TUBNC  ,3E15.5)
*     FLUID SIDE
      GF=WF/(TUBNC*ACI(4))
      X=(XIN+XOUT)/2.
      TI=(TMA+TIF)/2.
      WRITE (6,140)GF,X,TI
  140 FORMAT (10H GF,X,TI  ,3E15.5)
      CALL HT2PC(HTI,4,GF,TIF,TI,RHOV,RHOL,X)
*     AIRSIDE
      GA=WA/(ACO(4)*WCOND*TUBNC)
      CALL HTAC(HTO,4,GA,TMA)
      WRITE(6,150)GA,HTI,HTO
  150 FORMAT(13H GA,HTI,HTO  ,3E15.5)
      UINV=(1./HTI)+(1./HTO)
      U=1./UINV
      TUBEL=AU*UINV/(2.*(THCO+WCO)*TUBNC)
      WRITE(6,160)UINV,U,TUBEL
  160 FORMAT(15H UINV,U,TUBEL  ,3E15.5)
      SECTNS=TUBEL/WCOND
      WRITE(6,170)SECTNS
  170 FORMAT (9H SECTNS  ,E15.5)
      RETURN
      END
```

SUBROUTINE RGSIZE

The subroutine RGSIZE calculates the regenerator size required to raise the gas enthalpy from HAIN to HAOUT. The gas flow rate, liquid flow rate, and inlet temperature are input and a NTU calculation is carried out for a particular heat exchanger design.

RGSIZE uses the following subroutines:

- FCWV
- FCWL
- RGEOMC
- HT1PB
- HTWTM

The subroutine RGEOMC is similar to GEOMCO, and calculates hydraulic diameters and flow areas. HTWTM is similar to HTGTM, and calculates heat transfer coefficient for a ball-matrix heat exchanger. The COMMON of RGSIZE must be consistent with the COMMON's for all subroutines employed.

RGSIZE is written for a ball-matrix or round-tube heat exchanger.

NOMENCLATURE -- RGSIZE

FORTRAN Variables in COMMON:

There is no COMMON block in RGSIZE.

FORTRAN Variables in READ Statements:*

FORTRAN Variable	Definition	Units
HAIN	Inlet gas enthalpy	Btu/lb
HAOUT	Exit gas enthalpy	Btu/lb
LT	Tube length per liquid flow pass	ft
NFSECT	Number of gas flow sections	--
PPF	Fluid pressure	psi
PPG	Gas pressure	psi
TAIN	Inlet gas temperature	°F
TAOUT	Exit gas temperature	°F
TFIN	Inlet fluid temperature	°F
WAT	Gas mass flow rate	lb/in.
WFT	Liquid mass flow rate	lb/hr

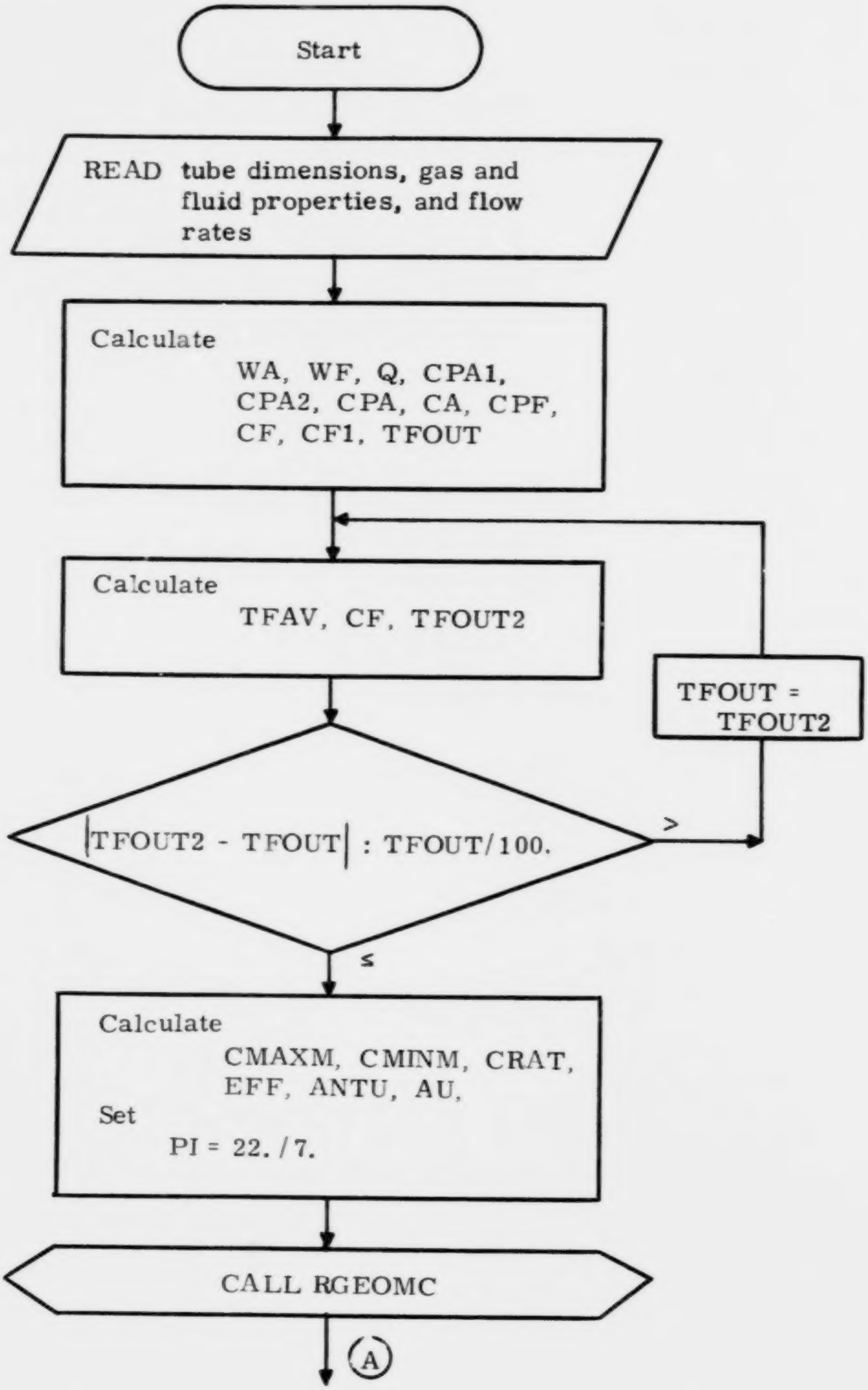
---

*See MAINSYS for the remainder of these variables.

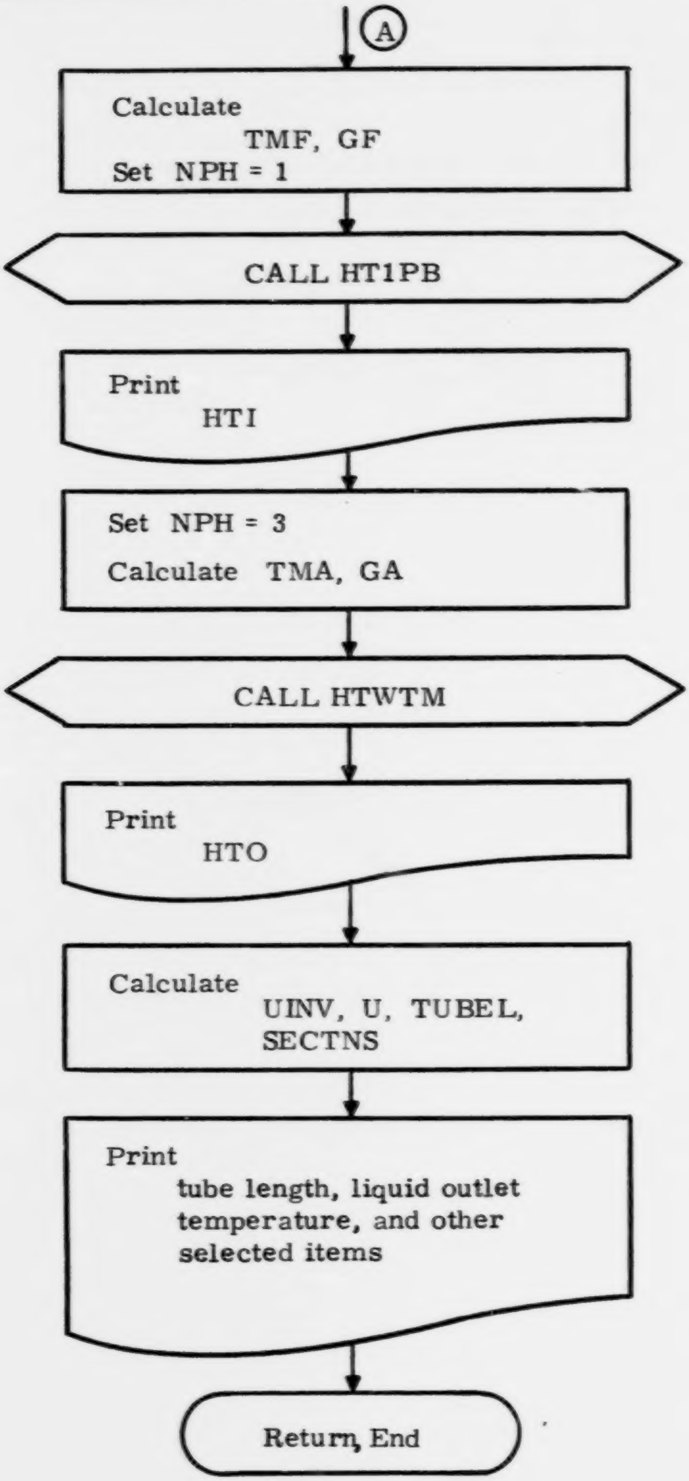
Other Selected FORTRAN Variables:

FORTRAN Variable	Definition	Units
ANTU	Number of NTU's	--
CA	Gas heat capacity	Btu/hr
CF	Liquid heat capacity	Btu/hr
EFF	Heat exchanger effectiveness	--
SECTNS	Number of liquid flow passes	--
TFOUT	Liquid exit temperature	°F
TUBEL	Tube length	in.

FLOW DIAGRAM -- RGSIZE


Start
READ tube dimensions, gas and fluid properties, and flow rates
Calculate WA, WF, Q, CPA1, CPA2, CPA, CA, CPF, CF, CF1, TFOUT
Calculate TFAV, CF, TFOUT2
|TFOUT2 - TFOUT| : TFOUT/100.
>
TFOUT = TFOUT2
≤
Calculate CMAXM, CMINM, CRAT, EFF, ANTU, AU,
Set PI = 22. / 7.
CALL RGEOMC
A

FLOW DIAGRAM -- RGSIZE (Cont'd)


A
Calculate
TMF, GF
Set NPH = 1
CALL HT1PB
Print
HTI
Set NPH = 3
Calculate TMA, GA
CALL HTWTM
Print
HTO
Calculate
UINV, U, TUBEL,
SECTNS
Print
tube length, liquid outlet
temperature, and other
selected items
Return, End

PROGRAM LISTING -- RGSIZE

```
      SUBROUTINE RGSIZE
*     REGENERATOR SIZING
*     SINGLE PHASE FLUID
*     CROSS FLOW
      REAL   L,MWVO
      REAL LT,NFSECT
      READ(21,200)LINE,DO(1),DI(1),NSU(1),NSI(1),X2L(1)
 100  FORMAT(I6,5F10.4)
      READ(21,100)LINE,FNO(1),FHO(1),FTO(1)
      READ(21,100)LINE,FNI(1),FHI(1),FTI(1)
      READ(21,100)LINE,PS(1),BH(1),BT(1)
      READ(21,100)LINE,WAT,TAIN,TAOUT,HAIN,HAOUT
 200  FORMAT(I6,2F10.4,2I10,F10.4)
      READ(21,100)LINE,WFT,TFIN
      READ(21,100)LINE,PPF,PPG
      READ(21,250)LINE,NM(1),NMO(1),NMI(1)
      READ(21,100)LINE,RM(1)
      READ(21,100)LINE,NFSECT,LT
      WA=WAT/NFSECT
      WF=WFT/NFSECT
 250  FORMAT(I6,3I10)
      Q=WA*(HAIN-HAOUT)
      CPA1=FCWV(PPG,TAIN)
      CPA2=FCWV(PPG,TAOUT)
      CPA=(CPA1+CPA2)/2.
      CA=WA*CPA
      CPF=FCWL(TFIN)
      CF=WF*CPF
      CF1=CF
      TFOUT=TFIN+(Q/CF)
 280  TFAV=(TFIN+TFOUT)/2.
      CF=WF*FCWL(TFAV)
      TFOUT2=TFIN+(Q/CF)
      IF(ABS(TFOUT2-TFOUT)-TFOUT/100.)270,270,260
 260  TFOUT=TFOUT2
      GO TO 280
 270  CONTINUE
      CMAXM=AMAX1(CA,CF)
      CMINM=AMIN1(CA,CF)
      CRAT=CMAXM/CMINM
      EFF=Q/(CMINM*(TAIN-TFIN))
      ANTU=-(ALOG((1.-EFF)/(1.-EFF/CRAT))/(1.-1./CRAT))
      AU=ANTU*CMINM
      PI=22./7.
      CALL RGEOMC(1)
*     FLUID SIDE
      TMF=(TFIN+TFOUT)/2.
      GF=WF/(ACI(1))
      NPH=1
      CALL HT1PH(HTI,1,GF,PPF,TMF)
      WRITE(6,35)HTI
  35  FORMAT (8H HT1PH  ,E15.5)
*     GAS SIDE
      NPH=3
      TMA=(TAIN+TAOUT)/2.
  55  GA=WA/(ACO(1)*LT)
      CALL HTWTM(HTO,1,GA,TMA,PPG)
      WRITE(6,85)HTO
  85  FORMAT (8H HTGTM  ,E15.5)
      UINV=(1./(HTI*(DI(1)/DO(1))))+(1./HTO)
      U=1./UINV
      TUBEL=AU*UINV/(PI*DO(1))
```

PROGRAM LISTING -- RGSIZE (Cont'd)

```
      SECTNS=TUBEL/(LT*12.)
      WRITE(6,300)CA,CF,FFF
300   FORMAT (13H CA,CF,FFF    ,3E15.5)
      WRITE(6,301)ANTU,AU,TAOUT
301   FORMAT (17H ANTU,AU,TAOUT    ,3E15.5)
      WRITE(6,302)TMF,GF,HTI
302   FORMAT (14H TMF,GF,HTI    ,3E15.5)
      WRITE(6,303)TMA,GA,HTO
303   FORMAT (14H TMA,GA,HTO    ,3E15.5)
      WRITE(6,304)HTI1,HTI2,HTR
304   FORMAT (17H HTI1,HTI2,HTR    ,3E15.5)
      WRITE(6,305)U,UINV
305   FORMAT (10H U,UINV    ,2E15.5)
      WRITE(6,306)TUBEL
306   FORMAT (9H TUBEL    ,E15.5)
      WRITE(6,307)SECTNS
307   FORMAT(10H  SECTNS  ,E15.5)
      WRITE(6,308)TFOUT
308   FORMAT(9H TFOUT    ,E15.5)
      RETURN
      END
```

Section 13

TOTAL SYSTEM MODEL

Section 13

TOTAL SYSTEM MODEL

MAIN PROGRAM – MAINSYS

The total system model is entitled MAINSYS. To permit study of the system steady-state and transient behavior, MAINSYS uses the following subroutines:

COMBST
COND
DRIVER
ENGINE
PUMP
REGEN
SATP
SUPPT
TRANSM
VAPORG

MAINSYS reads the following data files:

File 38	Data Input
File 39	Data Initial
File 11	Transient Start
File 31	Route

The Transient Start File 11 supplies initial values for starting the program from a transient condition. Since the data in the file vary according to the particular transient start condition, a listing is not included here.

NOMENCLATURE -- MAINSYS

FORTRAN Variables in COMMON:

The FORTRAN variables listed below appear in the COMMON of MAINSYS.

FORTRAN Variable	Definition	Units
AP	Piston area	$in.^2$
B	Number of hydrogen moles in reaction	moles
CH	Unburned hydrocarbon emissions	$\frac{\text{grams}}{\text{grams of fuel}}$
CHR	Molecular weight of fuel	lb moles
CO	Carbon monoxide emissions	$\frac{\text{grams}}{\text{grams of fuel}}$
CO2P	Carbon dioxide in products	moles
CO2S	Carbon dioxide stoichiometric	moles
DCS	Hydraulic diameter of shell-tube flow passage	in.

FORTRAN Variable	Definition	Units
DCT	Hydraulic diameter of tube flow passage	in.
DTH	Integration time step	sec
EQUIV	Equivalence ratio	--
F	Fuel air ratio	--
FS	Stoichiometric fuel-air ratio	--
H2OP	Water vapor in products	moles
H2OS	Water vapor stoichiometric	moles
HP	Unburned hydrogen in products	moles
HR	Heat rate of combustor at design	10^6 Btu/hr
HTFLAM	Enthalpy of products of combustion at flame temperature	Btu/lb
HTIN	Enthalpy of products of combustion at air temperature	Btu/lb
LHV	Lower heating value of fuel	Btu/lb
LHVT	LHVT = (LHV) (MFUEL)	lb
LCS	Length of combustor shell	ft
LCT	Length of combustor tube	ft
MAIR	Mass flow of combustor air	lb/sec
MFLUID	Mass flow of fluid	lb/sec
MFUEL	Mass flow of fuel	lb/sec
N2P	Nitrogen in products	moles
N2R	Nitrogen in reactants	moles
N2S	Nitrogen stoichiometric	moles
NBENDA	Equivalent turbulent friction length due to bends in airflow paths	--
NBENDG	Equivalent friction length due to bends in gas-flow paths	--
NO	Nitrogen oxide emissions	$\frac{\text{grams}}{\text{grams of fuel}}$
NP	Number of pistons	--
O2P	Oxygen in products	moles

FORTRAN Variable	Definition	Units
O2R	Oxygen in reactants	moles
O2S	Oxygen stoichiometric	moles
PO	Ambient pressure	lb/in.^{2}
SP1	Reciprocating expander stroke	in.
SSA	Shell wetted area	in.^{2}
STA	Tube-air wetted area	in.^{2}
STG	Tube-gas wetted area	in.^{2}
TO	Ambient temperature	°F
WS	Combustor shell weight	lb
WT	Weight of combustor tube	lb
YEXT	External time step	sec
ACI(I)	Inner-flow cross-section area for fluid pass I	in.^{2}
ACO(I)	Outer-flow area per unit length for fluid pass I	in.
BH(I)	Tube outside dimension in direction of gas travel for rectangular tube for fluid pass I	in.
BT(I)	Tube inside dimension in direction of gas travel for rectangular tube for fluid pass I	in.
CTF	Fluid energy storage capacity per unit length	Btu/in. °F
CTFY(I)	Fluid energy storage capacity per unit length for fluid pass I	Btu/in. °F
CTT(I)	Tube energy storage capacity per unit length for fluid pass I	Btu/in. °F
CW	Specific heat of working fluid	Btu/lb. °F
DHI(I)	Inside hydraulic diameter for fluid pass I	in.
DHO(I)	Outside hydraulic diameter for fluid pass I	in.
DI(I) or	Tube inside dimensions in direction perpendicular to gas flow for rectangular tube for fluid pass I, or	in.

FORTRAN Variable	Definition	Units
DI(I)	Tube inside diameter for circular tube for fluid pass I	in.
DO(I)	Tube outside dimension in direction perpendicular to gas flow for rectangular tube for fluid pass I, or	in.
	Tube outside diameter for circular tube for fluid pass I	in.
DS(I)	Sphere diameter for ball-matrix configuration for fluid pass I	in.
DYYY(I)	Stability time step for fluid pass I	sec
EF	Fluid-transport parameter (= mass flow rate × specific heat)	Btu/sec °F
EFY(I, J)	Fluid-transport parameter for fluid pass I, node J	Btu/sec °F
EG	Gas-transport parameter (= mass flow rate × specific heat)	Btu/sec °F
EGY(I, J)	Gas-transport parameter for fluid pass I, node J	Btu/sec °F
FHI(I)	Inside fin height for fluid pass I	in.
FHO(I)	Outside fin height for fluid pass I	in.
FNI(I)	Number of fins inside for fluid pass I	--
FNO(I)	Number of fins per inch outside for fluid pass I	1/in.
FRAC	Ratio of actual to stability step size	--
FTI(I)	Inside fin thickness for fluid pass I	in.
FTO(I)	Outside fin thickness for fluid pass I	in.
GVZ(I, J, K)	Specific volume of fluid for fluid pass I, node J	ft^3/lb
HF(I, J, K)	Fluid enthalpy for fluid pass I, node J, at time K K = 1, present K = 2, future	Btu/lb
HFIN1(I)	Fluid enthalpy at entrance of fluid pass I	Btu/lb
HFIN2(I)	Fluid enthalpy at exit of fluid pass I	Btu/lb
HGIN1(I)	Gas enthalpy at entrance of fluid pass I	Btu/lb

FORTRAN Variable	Definition	Units
HGIN2(I)	Gas enthalpy at exit of fluid pass I	Btu/lb
HGT	(Heat transfer coefficient x perimeter) between gas and tube	Btu/sec-in. °F
HGTY(I, J)	(Heat transfer coefficient x perimeter) between gas and tube for fluid pass I, node J	Btu/sec-in. °F
HTF	(Heat transfer coefficient x perimeter) between tube and fluid	Btu/sec-in. °F
HTFY(I, J)	(Heat transfer coefficient x perimeter) between tube and fluid for fluid pass I, node J	Btu/sec-in. °F
J2E(I)	Index to locate liquid-vapor interphase	--
J3E(I)	Index to locate end of superheat	--
L(I)	Total length of tube for fluid pass I	ft
LSTEP	Counter of timesteps	--
MWZ(I, J)	Fluid mass flow rate of fluid pass I, node J	lb/sec
NCLY(M)	Sequence number for the first fluid pass for component M	--
NCRY(M)	Sequence number for the last fluid pass for component M	--
NCY(M)	Number of fluid passes for component M	--
NCYCLE	Logic variable to bypass geometric constants and initialization within component program after first run =0 - initialize geometric constants ≠0 - bypass initialization	--
NFSECT(3)	Number of flow sections for tube and shell fluids	--
NLUMP	Maximum number of lumps for any fluid pass	--
NM(I)	Tube metal for fluid pass I If value = 1, then steel If value = 2, then copper	--
NMI(I)	Inside additional surface metal for fluid pass I	--

FORTRAN Variable	Definition	Units
NMO(I)	Outside additional surface metal for fluid pass I } If value = 1, then steel If value = 2, then copper	--
NPH	Nature of fluid phase 1 - subcooled 2 - saturated 3 - superheated	--
NPHY(I, J)	Nature of fluid phase for fluid pass I, node J	--
NPRINT	Logic variable for printing 0 - print 1 - bypass prints	--
NSI(I)	Type of heat transfer surface inside for fluid pass I 1 - bare 2 - finned or tape	--
NSO(I)	Type of heat transfer surface outside for fluid pass I 1 - bare 2 - finned 3 - ball-matrix	--
NSS	Logic variable for optional use of iteration program 0 - bypass iteration program 1 - use steady-state iteration program	--
NTRANS	Logic variable for optional transient start 0 - start from end point values 1 - start from given distribution	--
NX2MAX(I)	Maximum number of lumps required for fluid pass I	--
NX2Z(I)	Number of lumps in fluid pass I	--
NXN	Required number of distance lumps at future time	--
NXO	Required number of distance lumps at present time	--

FORTRAN Variable	Definition Definition	Units
PGV(I)	Gas pressure at inlet of fluid pass I	lb/in.^{2}
RFA	Ratio of fuel to air	--
RM(I)	Ball-matrix porosity for fluid pass I	--
RW	Density of working fluid	lb/ft^3
RWV(I, J)	Density of working fluid for fluid pass I, node J	lb/ft^3
TG1(I)	Inlet gas temperature for fluid pass I	°F
TG2(I, J, K)	Exit gas temperature for fluid pass I, node J, at time K K = 1 - present K = 2 - future	°F
TG2AVG(I)	Average exit gas temperature for fluid pass I	°F
TGIN1(I)	Temperature of gas at inlet of fluid pass I	°F
TGIN2(I)	Temperature of gas at exit of fluid pass I	°F
TIME	Real time	sec
TT(I, J, K)	Tube temperature for fluid pass I, node J, at time K K = 1 - present K = 2 - future	°F
TUBROW(I)	Number of gas passes for fluid pass I	--
VAPL1(I)	Fluid volume of pass I occupied by subcooled phase	in.^{3}
VAPL2(I)	Fluid volume of pass I occupied by boiling phase	in.^{3}
VAPL3(I)	Fluid volume of pass I occupied by superheat phase	in.^{3}
VOL(I)	Volume per unit length for fluid pass I	in.^{2}
X1G(I)	Geometric spacing between concentric coils for fluid pass I	in.
X2L(I)	Longitudinal pitch for fluid pass I	in.
X2T(I)	[Note: This variable is no longer used.]	

FORTRAN Variable	Definition	Units
CTAB(L, M)	Superheated working fluid specific heat at pressure PTAB(L), temperature TTAB(M)	Btu/lb °F
HLIQ(N)	Saturated working fluid liquid phase enthalpy at pressure P(N)	Btu/lb
HTAB(L, M)	Superheated working fluid enthalpy at pressure PTAB(L), temperature TTAB(M)	Btu/lb
HVAP(N)	Saturated working fluid vapor phase enthalpy at pressure P(N)	Btu/lb
IND	Logic variable for superheated interpolation program ≤ 1 - read superheated fluid tables > 1 - don't read tables	--
NLINE	Number of saturated fluid temperature steps	--
NND	Logic variable for saturated interpolation program ≤ 1 - read saturated fluid table > 1 - don't read table	--
NPSTEP	Number of superheated fluid pressure steps	--
NTSTEP	Number of superheated fluid temperature steps	--
P(N)	Saturated working fluid pressure	lb/in.^{2}
PTAB(L)	Pressure of superheated working fluid	lb/in.^{2}
STAB(L, M)	Superheated working fluid entropy at pressure PTAB(L), temperature TTAB(M)	Btu/lb °F
T(N)	Saturated working fluid temperature at pressure P(N)	°F
TTAB(M)	Temperature of superheated working fluid	°F
VLIQ(N)	Saturated working fluid liquid-phase specific volume at pressure P(N)	ft^3/lb

FORTRAN Variable	Definition	Units
VTAB(L, M)	Superheated working fluid specific volume at pressure PTAB(L), temperature TTAB(M)	ft^3/lb
VVAP(N)	Saturated working fluid vapor-phase specific volume at pressure P(N)	ft^3/lb

FORTRAN Variables in READ Statements:

Constant FORTRAN Variables*

FORTRAN Variable	Definition	Units
AF	Vehicle frontal area	ft^2
CD	Air drag coefficient	--
DISP	Maximum displacement	in.
KO	Acceleration sensitivity	--
M	Rotational moment of inertia of rotating components	$lb\ ft\ sec^2$
NBURNR	Number of burners	--
NPCYL	Number of cylinders	--
NTCOMP	Number of heat exchangers	--
RADW	Tire radius	ft
W	Vehicle weight	lb

Initialization FORTRAN Variables*

FORTRAN Variable	Definition	Units
AS	Accelerator setting ($0 \leq AS \leq 1$)	--
CS	Logic variable for driver action during wheel slip +1 - accelerator settings 0, -1 - accelerator setting held constant	--
DIST	Distance along route	miles

---

*See COMMON for the remainder of these variables.

FORTRAN Variable	Definition	Units
DT	Time step for vehicle integration	sec
HWCI	Enthalpy of working fluid at condenser inlet	Btu/lb
HWRI	Enthalpy of working fluid at regenerator inlet	Btu/lb
HWVI	Enthalpy of working fluid at vapor generator inlet	Btu/lb
INE	Logic variable to read data	--
LINBX	Logic variable: when =0, MAINSYS reads new line of data from ROUTE	--
LINDEX	Logic variable: when =1, vehicle idling	--
LINEX	Logic variable: when ≠0, vehicle decelerating; =0, vehicle accelerating	--
MGCI	Mass flow rate of gas at condenser inlet	lb/sec
MWCE	Mass flow rate of working fluid at condenser exit	lb/sec
MWCI	Mass flow rate of working fluid at condenser inlet	lb/sec
MWRE	Mass flow rate of working fluid at regenerator exit	lb/sec
MWRI	Mass flow rate of working fluid at regenerator inlet	lb/sec
MWVE	Mass flow rate of working fluid at vapor generator exit	lb/sec
MWVI	Mass flow rate of working fluid at vapor generator inlet	lb/sec
NST	Logic variable to control printing interval during transients 0 - print last timestep 1 - print every timestep	--
PGRI	Pressure of gas at regenerator inlet	lb/in.^{2}
PWCI	Pressure of working fluid at condenser inlet	lb/in.^{2}
PWRI	Pressure of working fluid at Regenerator inlet	lb/in.^{2}

FORTRAN Variable	Definition	Units
PWVI	Pressure of working fluid at vapor generator inlet	lb/in.^{2}
R	Engine intake ratio	--
RFUEL	Reference fuel flow rate for emission calculations	lb/sec
RPME	Engine rpm	rpm
RPMP	Pump rpm	rpm
RPMX	Transmission rpm	rpm
RPUMP	Variable displacement ratio	--
TIMEX	Time	sec
V	Vehicle speed	mph
VT	Tire speed at periphery	mph
Z	Logic variable used during wheel slip: initially set Z=1; reset internally	--

Transient Start FORTRAN Variables*

FORTRAN Variable	Definition	Units
TIM(M)	Starting time for transient start for component M	sec

ROUTE FORTRAN Variables*

FORTRAN Variable	Definition	Units
AR	Reference acceleration	ft/sec^2
CR	Logic variable +1 - indicates acceleration 0 - cruise at constant speed -1 - indicates deceleration	--
G	Grade %	--
KF	Maximum friction coefficient (traction limit)	--
LR	Next marker position	miles

---

*See COMMON for the remainder of these variables

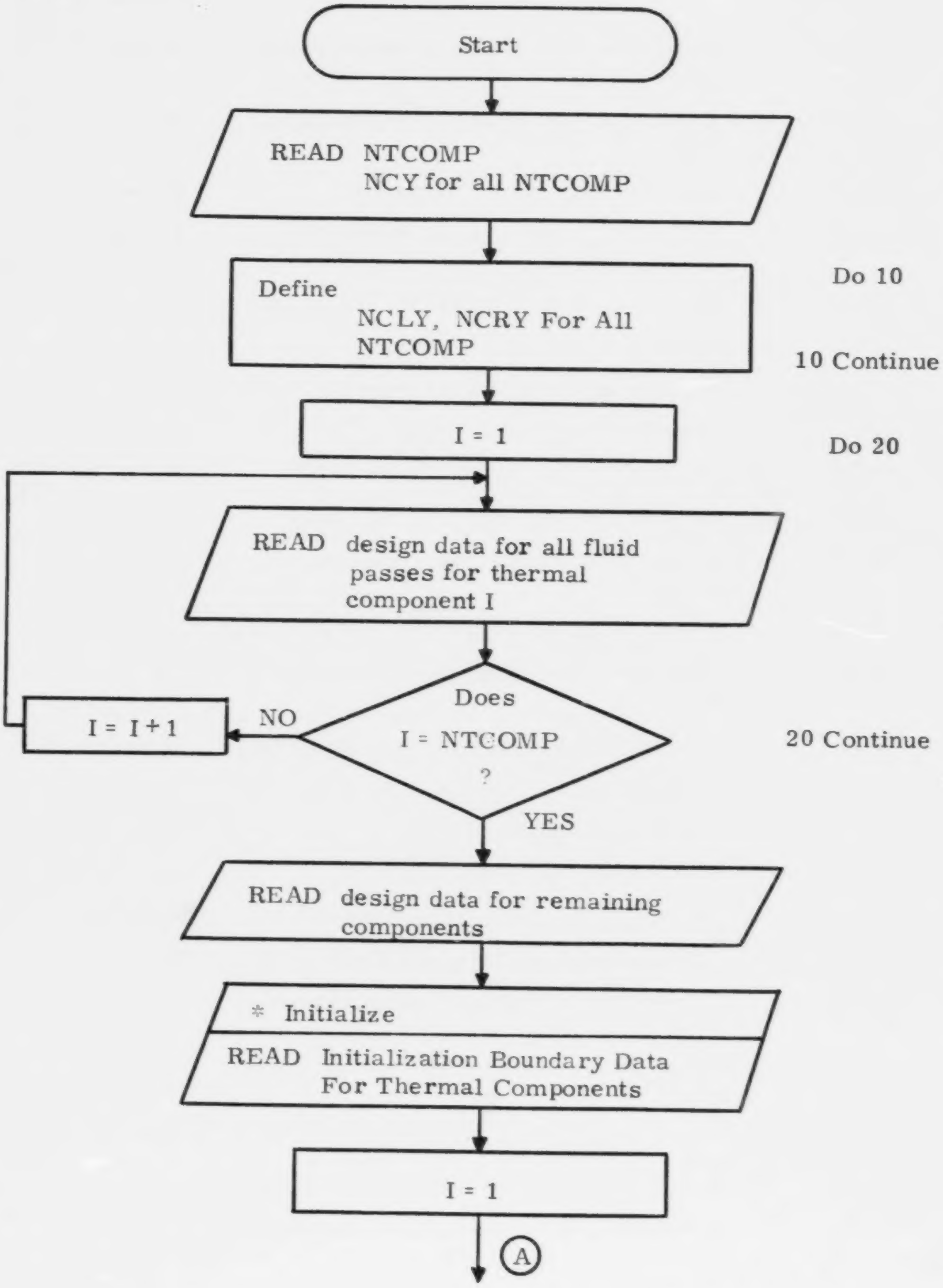
FORTRAN Variable	Definition	Units
TI	Maximum idle time	sec
VR	Reference vehicle velocity (speed limit)	mph

Other Selected FORTRAN Variables:

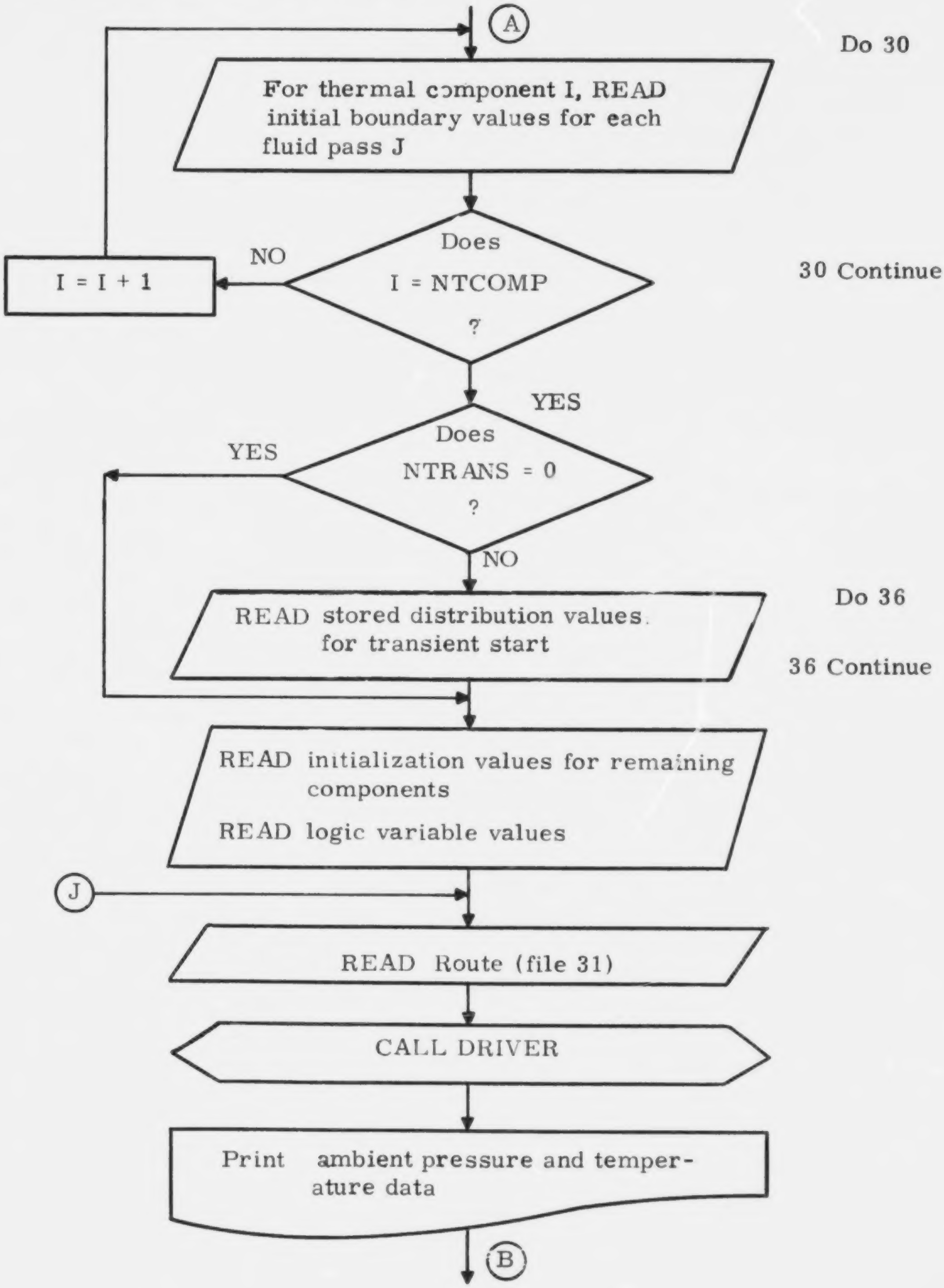
FORTRAN Variable	Definition	Units
A	Vehicle acceleration	ft/sec^2
AA	Linear acceleration of vehicle wheel	ft/sec^2
CWP	Specific heat of working fluid	Btu/lb °F
DA	Aerodynamic drag	lb
DG	Grade drag	lb
DIFF	Per unit enthalpy difference	--
DR	Rolling and mechanical resistance	lb
FM	Maximum tractive effort	lb
FT	Tractive effort	lb
HGRE	Enthalpy of vapor at regenerator exit	Btu/lb
HGRI	Enthalpy of vapor at regenerator inlet	Btu/lb
HWCE	Enthalpy of working fluid at condenser exit	Btu/lb
HWEI	Enthalpy of working fluid at engine inlet	Btu/lb
HWPE	Enthalpy of working fluid at pump exit	Btu/lb
HWRE	Enthalpy of working fluid at regenerator exit	Btu/lb
HWVE	Enthalpy of working fluid at vapor generator exit	Btu/lb
IX	Local logic variable	--
JS	Variable to denote cumulative number of timesteps	--
KA	Accelerator sensitivity (changed internally)	--
KO	Accelerator sensitivity (initial value)	--
MGI	Mass flow rate of gas at inlet	lb/sec

FORTRAN Variable	Definition	Units
MGRE	Mass flow rate of gas at regenerator exit	lb/sec
MGRI	Mass flow rate of gas at regenerator inlet	lb/sec
MGV	Gas flow rate for each burner	lb/sec
MGVI	Mass flow rate of gas at vapor generator inlet	lb/sec
MWE	Mass flow rate of working fluid at exit	lb/sec
NCL	Number of the first fluid pass	--
NCR	Number of the last fluid pass	--
NX2	Required number of lumps	--
PACI	Pressure of air at condenser inlet	lb/in.^{2}
PGCI	Pressure of gas at condenser inlet	lb/in.^{2}
PGVI	Pressure of gas at vapor generator inlet	lb/in.^{2}
PWEE	Pressure of working fluid at engine exit	lb/in.^{2}
PWEI	Pressure of working fluid at engine inlet	lb/in.^{2}
PWPE	Pressure of working fluid at pump exit	lb/in.^{2}
PWPI	Pressure of working fluid at pump inlet	lb/in.^{2}
TAUX	Auxiliary torque	ft-lb
TE	Cumulative idle time	sec
TENET	Net torque at inlet of transmission	ft-lb
TGCI	Temperature of gas at condenser inlet	°F
TGVI	Temperature of gas at vapor generator inlet	°F
TWPI	Temperature of working fluid at pump inlet	°F
TX	Temperature of working fluid	°F
TX1	Subcooled temperature of working fluid	°F
WN	Horizontal component of vehicle weight	lb

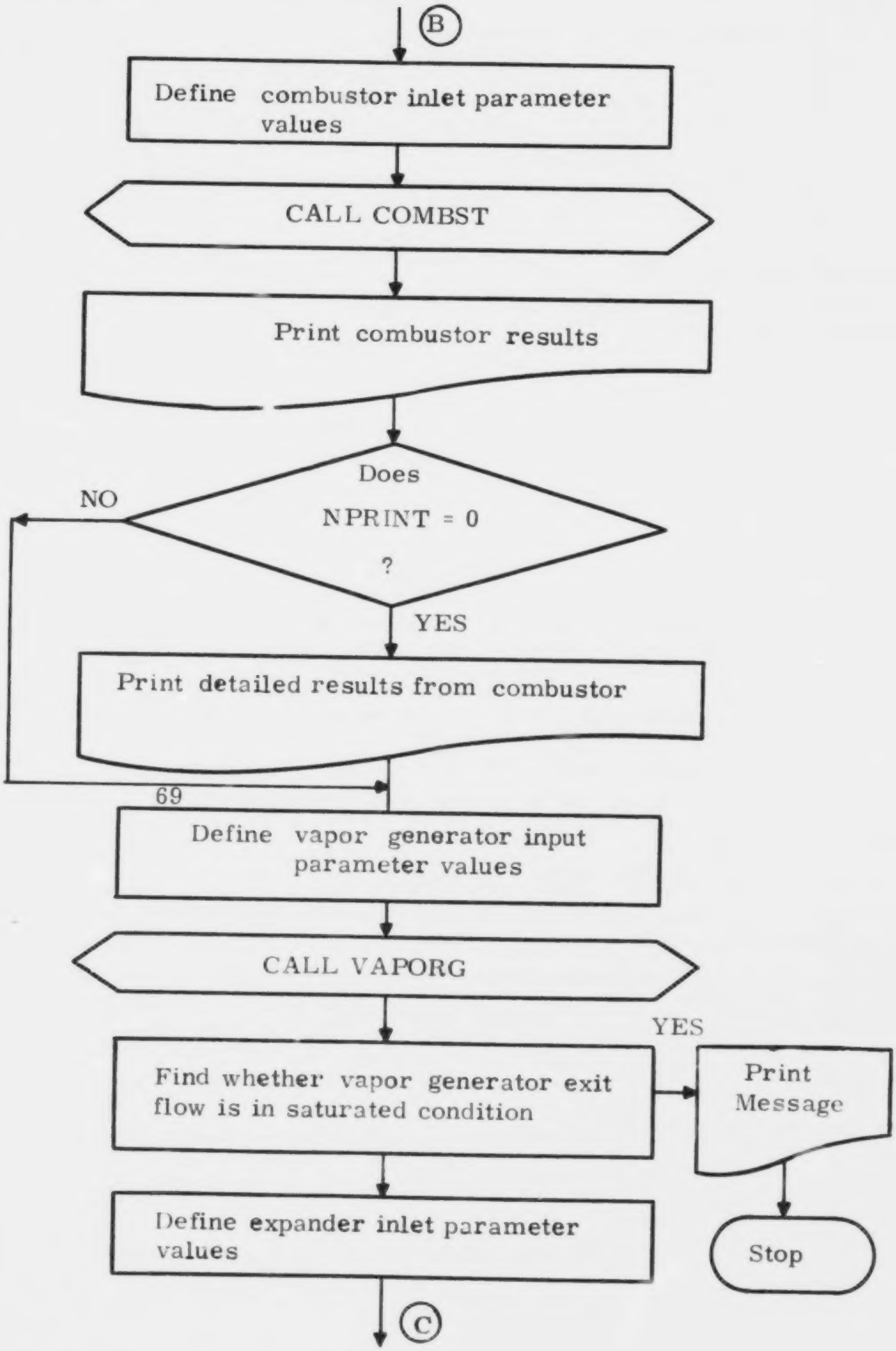
FLOW DIAGRAM -- MAINSYS


Start
READ NTCOMP
NCY for all NTCOMP
Define
NCLY, NCRY For All NTCOMP
Do 10
10 Continue
I = 1
Do 20
READ design data for all fluid passes for thermal component I
Does
I = NTCOMP
?
NO
I = I + 1
YES
20 Continue
READ design data for remaining components
* Initialize
READ Initialization Boundary Data For Thermal Components
I = 1
A

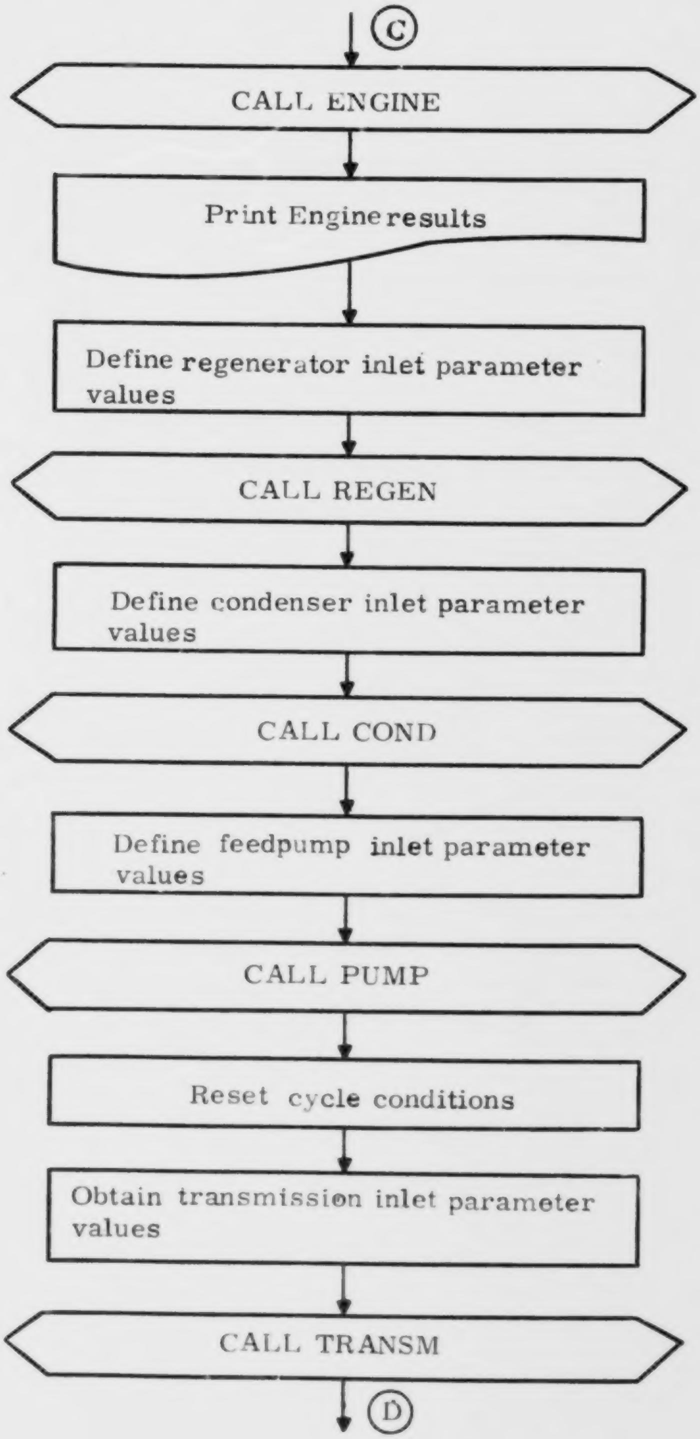
FLOW DIAGRAM -- MAINSYS (Cont'd)


A
Do 30
For thermal component I, READ initial boundary values for each fluid pass J
Does I = NTCOMP ?
NO
I = I + 1
30 Continue
YES
Does NTRANS = 0 ?
YES
NO
Do 36
READ stored distribution values for transient start
36 Continue
READ initialization values for remaining components
READ logic variable values
J
READ Route (file 31)
CALL DRIVER
Print ambient pressure and temperature data
B

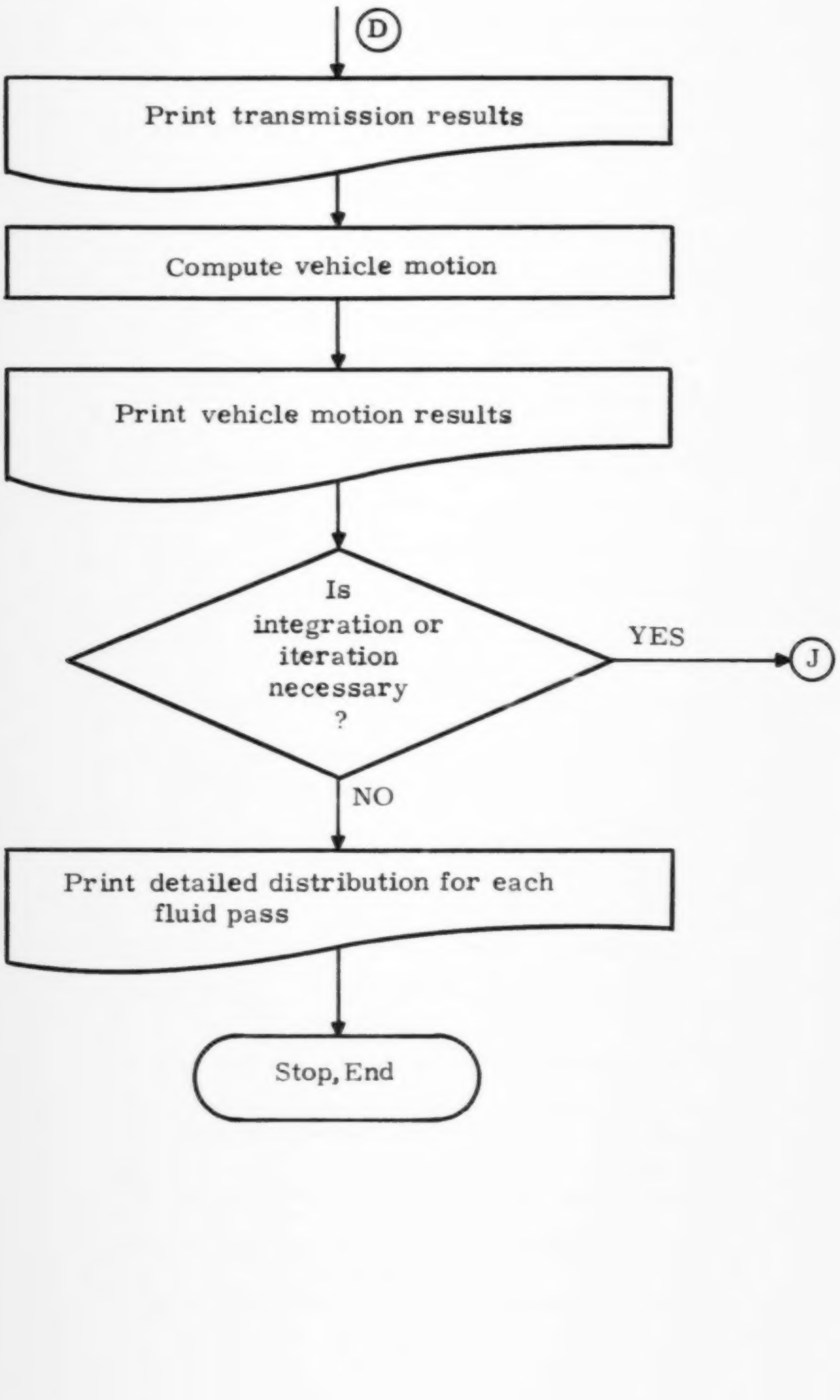
FLOW DIAGRAM -- MAINSYS (Cont'd)


B
Define combustor inlet parameter values
CALL COMBST
Print combustor results
Does NPRINT = 0 ?
NO
YES
Print detailed results from combustor
69
Define vapor generator input parameter values
CALL VAPORG
YES
Find whether vapor generator exit flow is in saturated condition
Print Message
Stop
Define expander inlet parameter values
C

FLOW DIAGRAM -- MAINSYS (Cont'd)


C
CALL ENGINE
Print Engine results
Define regenerator inlet parameter values
CALL REGEN
Define condenser inlet parameter values
CALL COND
Define feedpump inlet parameter values
CALL PUMP
Reset cycle conditions
Obtain transmission inlet parameter values
CALL TRANSM
D

FLOW DIAGRAM -- MAINSYS (Cont'd)


D
Print transmission results
Compute vehicle motion
Print vehicle motion results
Is integration or iteration necessary ?
YES
J
NO
Print detailed distribution for each fluid pass
Stop, End

PROGRAM LISTING -- MAINSYS

```
      COMMON AP,B,CH,CHR,CO
      COMMON CO2P,CO2S,DCS,DCT,DTH
      COMMON EQUIV,F,FS,H2OP,H2OS
      COMMON HP,HR,HTFLAM,HTIN,LHV
      COMMON LHVT,LCS,LCT,MAIR,MFLUID
      COMMON MFUEL,N2P,N2R,N2S,NBENDA
      COMMON NBENDG,NU,NP,O2P,O2R
      COMMON O2S,PO,SP1,SSA,STA
      COMMON STG,TO,WS,WT,YEXT
      COMMON ACI(10),ACO(10),BH(10),BT(10),CTF
      COMMON CTFY(10,11),CTT(10),CW,DHI(10),DHO(10)
      COMMON DI(10),DO(10),DS(10),DYYY(10),EF
      COMMON EFY(10,11),EG,EGY(10,11),FHI(10),FHO(10)
      COMMON FNI(10),FNO(10),FRAC,FTI(10),FTO(10)
      COMMON GVZ(10,11,2),HF(10,11,2),HFIN1(10),HFIN2(10),HGIN1(10)
      COMMON HGIN2(10),HGI,HGTY(10,11),HTF,HTFY(10,11)
      COMMON J2E(10),J3E(10),L(10),LSTEP,MWZ(10,11)
      COMMON NCY(3),NCLY(3),NCRY(3),NCYCLE,NFSECT(3)
      COMMON NLUMP,NM(10),NMI(10),NMO(10),NPH
      COMMON NPHY(10,11),NPRINT,NSS,NSI(10),NSO(10)
      COMMON NTRANS,NX2MAX(10),NX2Z(10),NXN,NXO
      COMMON PGV(10),RFA,RM(10),RW,RWY(10,11)
      COMMON TG1(10),TG2(10,11,2),TG2AVG(10),TGIN1(10),TGIN2(10)
      COMMON TIME,TT(10,11,2),TUBROW(10),VAPL1(10),VAPL2(10)
      COMMON VAPL3(10),VOL(10),X1G(10),X2L(10),X2T(10)
      COMMON CTAB(69,27),HLIQ(128),HTAB(69,27),HVAP(128),IND
      COMMON NLINE,NND,NPSTEP,NTSTEP,P(128)
      COMMON PTAB(70),STAB(69,27),T(128),TTAB(33),VLIQ(128)
      COMMON VTAB(69,27),VVAP(128)
      REAL   L,LHV,LHVT,LCS,LCT,MAIR,MFLUID,MFUEL,MWZ,N2P,N2R,N2S,NO
      REAL MWVI,MWVE,MWCI,MWCE,MWRI,MWRE,MWE,MWP,MWEE
      REAL MGV,MGVI,MGCI,MGRI,MGRE,MGI,MGE
      REAL KF,LR,KO,KA,M
      DIMENSION TIM(3)
      INTEGER CR,Z
      NLUMP=10
      READ(38,18)LINE,NTCOMP
      READ(38,18)LINE,(NCY(I),I=1,NTCOMP)
      NCLY(1)=1
      DO 10 I=2,NTCOMP
      NCLY(I)=NCLY(I-1)+NCY(I-1)
10    NCRY(I-1)=NCLY(I)-1
      NCRY(NTCOMP)=NCLY(NTCOMP)+NCY(NTCOMP)-1
      DO 20 I=1,NTCOMP
      J1=NCLY(I)
      J2=NCRY(I)
      READ(38,15)LINE,(BH(J),J=J1,J2)
      READ(38,15)LINE,(BT(J),J=J1,J2)
      READ(38,15)LINE,(DI(J),J=J1,J2)
      READ(38,15)LINE,(DO(J),J=J1,J2)
      READ(38,15)LINE,(L(J),J=J1,J2)
      READ(38,18)LINE,(NM(J),J=J1,J2)
      READ(38,15)LINE,(X1G(J),J=J1,J2)
      READ(38,15)LINE,(X2L(J),J=J1,J2)
      READ(38,15)LINE,(X2T(J),J=J1,J2)
      READ(38,15)LINE,(DS(J),J=J1,J2)
      READ(38,15)LINE,(FHI(J),J=J1,J2)
      READ(38,15)LINE,(FHO(J),J=J1,J2)
      READ(38,15)LINE,(FNI(J),J=J1,J2)
      READ(38,15)LINE,(FNO(J),J=J1,J2)
      READ(38,15)LINE,(FTI(J),J=J1,J2)
      READ(38,15)LINE,(FTO(J),J=J1,J2)
      READ(38,18)LINE,(NMI(J),J=J1,J2)
      READ(38,18)LINE,(NMO(J),J=J1,J2)
      READ(38,18)LINE,(NSI(J),J=J1,J2)
      READ(38,18)LINE,(NSO(J),J=J1,J2)
      READ(38,15)LINE,(RM(J),J=J1,J2)
      READ(38,15)LINE,(TUBROW(J),J=J1,J2)
      READ(38,18)LINE,NFSECI(I)
   20 CONTINUE
      READ(38,22)LINE,SP1,NP,AP
      READ(38,22)LINE,DISP,NPCYL
   22 FORMAT(I6,F12.5,I12,F12.5)
      READ(38,18)LINE,NBURNR
      READ(38,15)LINE,SSA,STA,STG
      READ(38,15)LINE,WS,WT,DCS,DCT
      READ(38,18)LINE,NBENDA,NBENDG
      READ(38,15)LINE,LHV,LCS,LCT
      READ(38,15)LINE,AF,CD,W,RADW,KO
      READ(38,15)LINE,M
*     INITIALIZATION
      NTRANS=0
      READ(39,15)LINE,PWVI,HWVI,MWVI,MWVE
      READ(39,15)LINE,PWCI,HWCI,MWCI,MWCE,MGCI
      READ(39,15)LINE,PWRI,HWRI,MWRI,MWRE,PGRI
      READ(39,15)LINE,PWVE,PWCE
      DO 30 I=1,NTCOMP
      J1=NCLY(I)
      J2=NCRY(I)
      READ(39,15)LINE,(HFIN1(J),J=J1,J2)
      READ(39,15)LINE,(HFIN2(J),J=J1,J2)
      IF(I.EQ.3) GO TO 25
      READ(39,15)LINE,(TGIN1(J),J=J1,J2)
      READ(39,15)LINE,(TGIN2(J),J=J1,J2)
      GO TO 30
   25 CONTINUE
      READ(39,15)LINE,(HGIN1(J),J=J1,J2)
      READ(39,15)LINE,(HGIN2(J),J=J1,J2)
   30 CONTINUE
      IF(NTRANS.EQ.0) GO TO 39
   32 CONTINUE
*     DO 36 I=1,NTCOMP
      J1=NCLY(I)
      J2=NCRY(I)
      READ(11,101)TIM(I)
  101 FORMAT(4E15.5)
      DO 33 J=J1,J2
   33 READ(11,102)NX27(J)
  102 FORMAT(I10)
      DO 35 IK=J1,J2
      MI=NX27(IK)
      DO 34 J=1,MI
   34 READ(11,101)HF(IK,J+1,1),TT(IK,J,1),TG2(IK,J,1),MWZ(IK,J+1)
      IF(IK.NE.J2)MWZ(IK+1,1)=MWZ(IK,MI+1)
      IF(IK.NE.J2)HF(IK+1,1,1)=HF(IK,MI+1,1)
   35 CONTINUE
      READ(11,101)(TG1(J),J=J1,J2)
   36 CONTINUE
   39 READ(39,15)LINE,FRAC
```

PROGRAM LISTING -- MAINSYS (Cont'd)

```
      READ(39,18)LINE,LINDEX,LINEX,LINBX
      READ(39,15)LINE,MFUEL,MAIR,MFLUID,RFUEL
      READ(39,15)LINE,PO,TO
      READ(39,15)LINE,R,RPME
      READ(39,15)LINE,RPUMP,RPMP
      READ(39,15)LINE,YEXT,TIME,TIMEX,DT
      READ(39,18)LINE,IND,NND,NCYCLE
      READ(39,18)LINE,NPRINT,NSS,INE,NST
      READ(39,15)LINE,AS,DIST,V,VT
      READ(39,15)LINE,RPMX,CS
      READ(39,18)LINE,Z
      KA=KO
   15 FORMAT(I6,5F12.5)
   18 FORMAT(I6,5I12)
      IF(NLUMP.EQ.10) GO TO 59
   19 IF(LINDEX.EQ.1) GO TO 55
   40 TE=0.
      READ(31,50)LINE,LR,G,TI,AR,VR,KF,CR
   50 FORMAT(I6,6F8.2,I2)
   55 CALL DRIVER(TI,TE,AR,DT,DIST,LR,V,VT,Z,CS,KA,CR,VR,RADW,AS,
     7A,LINDEX,LINEX,LINBX,RPMX,KO,AA)
   60 CONTINUE
      IF(LINBX.NE.0) GO TO 19
   59 CONTINUE
      WRITE(6,61)PO,TO
   61 FORMAT(32H1AMBIENT PRES (PSIA), TEMP (F)  ,2E15.5)
      WRITE(6,613)TIME
  613 FORMAT(8H TIME   ,E15.5)
      TGCI=TO
      PACI=PO
      PGCI=PO
      MGV=MFUEL+MAIR
      RFA=MFUEL/MAIR
      HR=LHV*RFUEL*3600.*1.E-6
      WRITE(6,62)
   62 FORMAT(2H  )
      WRITE(6,63)
   63 FORMAT(48X,22H ***** COMBUSTOR *****)
      WRITE(6,62)
      CALL COMBST(PACI,PACE,TG,TSC,TAC,TTC,CPC,TFLAME)
      WRITE(6,201)
  201 FORMAT(19H ** FLOWS (LBS/SEC))
      WRITE(6,202)MAIR,MFUEL
  202 FORMAT(10X,10H AIR      ,E15.5,5X,10H FUEL     ,E15.5)
      WRITE(6,62)
      WRITE(6,203)
  203 FORMAT(20H ** TEMPERATURES (F))
      WRITE(6,204)TTC,TSC
  204 FORMAT(10X,10H TUBE     ,E15.5,5X,10H SHELL    ,E15.5)
      WRITE(6,205)TAC,TG
  205 FORMAT(10X,10H AIR      ,E15.5,5X,10H GAS      ,E15.5)
      WRITE(6,206)TFLAME
  206 FORMAT(10X,10H FLAME    ,E15.5)
      WRITE(6,62)
      WRITE(6,207)
  207 FORMAT(30H ** EMMISSIONS (GM/GM OF FUEL))
      WRITE(6,208)NO,CO,CH
  208 FORMAT(10X,10H NO       ,E15.5,5X,10H CO       ,E15.5,5X,
     710H CH       ,E15.5)
       IF(NPRINT.NE.0) GO TO 69
      WRITE(6,64)H,H2OS,CO2S,O2S
   64 FORMAT(18H H,H2OS,CO2S,O2S  ,4E15.5)
      WRITE(6,65)N2S,FS,F,EQUIV
   65 FORMAT(17H N2S,FS,F,EQUIV  ,4E15.5)
      WRITE(6,66)O2R,O2P,N2R,N2P
   66 FORMAT(18H O2R,O2P,N2R,N2P  ,4E15.5)
      WRITE(6,67)HP,CPC,H2OP,CO2P
   67 FORMAT(19H HP,CPC,H2OP,CO2P  ,4E15.5)
      WRITE(6,68)HTIN,LHVT,HTFLAM
   68 FORMAT(19H HTIN,LHVT,HTFLAM  ,3E15.5)
   69 CONTINUE
      PGVI=PACE
      TGVI=TG
      MGVI=MGV*FLOAT(NBURNR)
  200 CONTINUE
      LSTEP=3
      JS=0
      IF(NTRANS.NE.0) TIME=TIM(1)
      IX=1
      NCL=NCLY(IX)
      HF(NCL,1,1)=HWVI
      TGIN1(NCL+1)=TGVI
      MWZ(NCL,1)=MWVI/FLOAT(NFSECT(IX))
      MGI=MGVI/FLOAT(NFSECT(IX))
      MWE=MWVE/FLOAT(NFSECT(IX))
      WRITE(6,210)
  210 FORMAT(2H1 ,45X,28H ***** VAPOR GENERATOR *****)
      CALL VAPORG(MGI,MWF,PGVI,PGVE,PWVI,PWVE,TGVI,JS,NST)
      TIME=TIMEX
      NCR=NCRY(IX)
      NX2=NX2Z(NCR)
      HWVE=HF(NCR,NX2+1,1)
      NSS=1
      PWEI=PWVE
      HWEI=HWVE
      CALL SATP(PWEI,TWEI,VWL,VWV,HL,HV,1)
      IF(HWEI.GE.HV) GO TO 500
      WRITE(6,14)
   14 FORMAT(45H VAPOR GENERATOR EXIT IN SATURATION CONDITION)
      STOP
  500 CALL SUPPI(PWEI,TWEI,HWEI,SWEI,VWEI,3)
      PWEE=PGRI
      WRITE(6,501)
  501 FORMAT(2H1 ,48X,19H ***** ENGINE *****)
      WRITE(6,62)
      CALL ENGINE(R,RPME,PWEI,TWEI,HWEI,SWEI,VWEI,PWEE,TWEE,
     7HWEE,SWEE,VWEE,XWEE,MWEE,TORQE)
      WRITE(6,502)RPME,R
  502 FORMAT(24H ENGINE  SPEED, STROKE  ,2E15.5)
      WRITE(6,503)PWEI,HWEI
  503 FORMAT(24H INLET  PRES, ENTHALPY  ,2E15.5)
      WRITE(6,504)PWEE,HWEE
  504 FORMAT(24H EXIT  PRES, ENTHALPY   ,2E15.5)
      WRITE(6,505)MWEE
  505 FORMAT(24H MASS FLOW (LBS/SEC)    ,E15.5)
      WRITE(6,506)TORQE
  506 FORMAT(24H OUTPUT TORQUE          ,E15.5)
      MWVE=MWEE
      MGRI=MWEE
      HGRI=HWEE
```

PROGRAM LISTING -- MAINSYS (Cont'd)

```
 510  CONTINUE
      NCL=NCLY(3)
      NCR=NCRY(3)
      IF(NTRANS.EQ.0) GO TO 526
      DO 525 II=NCL,NCR
      WRITE(6,515)TG1(II)
 515  FORMAT(6H TG1  ,F12.5)
      DO 525 JJ=1,NLUMP
      WRITE(6,516)HF(II,JJ,1),TT(II,JJ,1),TG2(II,JJ,1),MWZ(II,JJ)
 516  FORMAT(5H HF  ,4F12.5)
525   CONTINUE
 526  CONTINUE
      JS=0
      IF(NTRANS.NE.0) TIME=TIM(3)
      IX=3
      NCL=NCLY(IX)
      NCR=NCRY(IX)
      HF(NCL,1,1)=HWRI
      HGIN1(NCR)=HGRI
      MWZ(NCL,1)=MWRI/FLOAT(NFSECT(IX))
      MGI=MGRI/FLOAT(NFSECT(IX))
      WRITE(6,507)
 507  FORMAT(2H1 ,46X,24H ***** REGENERATOR *****)
      CALL REGEN(MGI,MGE,PGRI,PGRE,PWRI,PWRE,HGRI,JS,NST)
      TIME=TIMEX
      JS=0
      NSS=1
      NX2=NX2Z(NCR)
      MGRE=MGE*FLOAT(NFSECT(IX))
      HGRE=HGIN2(NCL)
      HWRE=HF(NCR,NX2+1,1)
      MWRE=MWZ(NCR,NX2+1)*FLOAT(NFSECT(IX))
      PWVI=PWRE
      MWVI=MWRE
      MWCI=MGRE
      PWCI=PGRE
      HWCI=HGRE
      IF(NTRANS.NE.0) TIME=TIM(2)
      IX=2
      NCL=NCLY(IX)
      NCR=NCRY(IX)
      HF(NCL,1,1)=HWCI
      MWZ(NCL,1)=MWCI/FLOAT(NFSECT(IX))
      MGI=MGCI/FLOAT(NFSECT(IX))
      MWE=MWCE/FLOAT(NFSECT(IX))
      WRITE(6,508)
 508  FORMAT(2H1 ,47X,22H ***** CONDENSER *****)
      CALL COND(MGI,MWE,PGCI,PGCE,PWCI,PWCE,TGCI,JS,NST)
      TIME=TIMEX
      NSS=1
      NX2=NX2Z(NCR)
      HWCE=HF(NCR,NX2+1,1)
      MWCE=MWZ(NCR,NX2+1)*FLOAT(NFSECT(IX))
      HWRI=HWCE
      MWRI=MWCE
      PWPI=PWCE
      CALL SATP(PWPI,TWPI,DU,DD,HL,HV,1)
      IF(HWCE.GT.HL) GO TO 600
      TX=TWPI
```

PROGRAM LISTING -- MAINSYS (Cont'd)

```
 520  CWP=FCWL(TX)
      TX1=((HWCE-HL)/CWP)+TWPI
      IF(ABS((TX1-TX)/TX).LE.0.01) GO TO 550
      TX=(TX1+TX)/2.
      GO TO 520
 550  TWPI=TX1
 600  PWPE=PWVI+(PWRI-PWRE)
      CALL PUMP(RPUMP,RPMP,PWPI,PWPE,TWPI,MWP,HPUMP,DISP,NPCYL)
      WRITE(6,601)
 601  FORMAT(2H1 ,47X,22H ***** FEED PUMP *****)
      WRITE(6,602)RPUMP,RPMP
 602  FORMAT(20H STROKE,SPEED        ,2E15.5)
      WRITE(6,603)PWPI,TWPI
 603  FORMAT(20H INLET PRES, TEMP    ,2E15.5)
      WRITE(6,604)PWPE
 604  FORMAT(20H EXIT PRES           ,E15.5)
      WRITE(6,605)MWP,HPUMP
 605  FORMAT(20H FLOW,POWER          ,2E15.5)
      HWPE=HWCE
      HWRI=HWPE
      PWRI=PWPE
      MWRI=MWP
      TAUX=0.
      RPMX=1228.
      TENET=TORQE-TAUX
      WRITE(6,62)
      WRITE(6,62)
      WRITE(6,606)
 606  FORMAT(48X,25H ***** TRANSMISSION *****)
      CALL TRANSM(R,RPMX,TENET,RPME,TORQX,INE)
      WRITE(6,607)RPMX,R,TENET
 607  FORMAT(30H INPUT SPEED, STROKE, TORQUE  ,3E15.5)
      WRITE(6,608)RPME,TORQX
 608  FORMAT(30H OUTPUT SPEED, TORQUE         ,2E15.5)
*     VEHICLE MOTION
      TIME=TIME+DT
      TIMEX=TIMEX+DT
      IF(LINEX.NE.0) GO TO 180
      G=0.
      KF=.5
      V=90.
      AA=0.
      VT=90.
      WN=W*COS(ATAN(.01*G))
      FM=KF*WN
      DG=W*SIN(ATAN(.01*G))
      DR=(W/50.)*(1.+(1.4E-3*V/1.47)+(1.210E-5*(V/1.47)**2))
      DA=.0025*CD*AF*V**2
      FT=TORQX/RADW-M*AA/RADW
      IF(FT.GT.FM) GO TO 170
      IF(V-VT) 170,609,609
 609  VT=V
      A=(TORQX/RADW-DA-DR-DG)/(W/32.2+M/(RADW**2))
      AA=A/RADW
      GO TO 180
 170  A=(FM-DA-DR-DG)/(W/32.2)
      AA=(TORQX-FM*RADW)/M
 180  V=V+(1.5/1.47)*A*DT
      IF(V.LT.0.) V=0.
      VT=VT+RADW*(1.5/1.47)*AA*DT
```

PROGRAM LISTING -- MAINSYS (Cont'd)

```
      IF(VT.LT.0.) VT=0.
      RPMX=(44./3.14)*VT
      DIST=DIST+(1.5/3600.)*V*DT
      WRITE(6,62)
      WRITE(6,62)
      WRITE(6,611)
  611 FORMAT(47X,27H ***** VEHICLE MOTION *****)
      WRITE(6,612)V,DIST
  612 FORMAT(43H VEHICLE SPEED(MPH), DISTANCE TRAVELED(MI) ,2E15.5)
      WRITE(6,62)
      WRITE(6,62)
      IF(RPMX.LT.0.) RPMX=0.
      DIFF=ABS((HWRE-HWVI)/HWVI)
      IF(NLUMP.EQ.10) GO TO 615
      IF(DIFF.LT.0.05) GO TO 2000
      HWVI=(HWVI+HWRE)/2.
      NCYCLE=1
  615 WRITE(6,614)
  614 FORMAT(44H END-POINT DISTRIBUTION AFTER THIS ITERATION)
      DO 1500 I=1,NICOMP
      J1=NCLY(I)
      J2=NCRY(I)
      DO 1500 J=J1,J2
      J3=NX2Z(J)+1
      HFIN1(J)=HF(J,1,1)
      HFIN2(J)=HF(J,J3,1)
      TGIN1(J)=TG1(J)
      TGIN2(J)=TG2AVG(J)
      WRITE(6,1510)I,J,HFIN1(J),HFIN2(J),TGIN1(J),TGIN2(J),HGIN1(J)
     7,HGIN2(J)
 1510 FORMAT(10H MAINOUT  ,2I5,6E15.5)
 1500 CONTINUE
      IF(NLUMP.EQ.10) GO TO 2000
      GO TO 200
 2000 CONTINUE
      STOP
      END
```

DATA FILE - DATA INPUT

The Data Input File 38 supplies geometric and design data for all the system components. Figure 4 indicates the arrangement of the data in Data Input.

Reference No.			
00010	NTCOMP		
00020	NCY(1)	NCY(2)	NCY(3)
	Following Data Refer to Vapor Generator		
00030	BH(1)	BH(2)	BH(3)
00040	BT(1)	BT(2)	BT(3)
00050	DI(1)	DI(2)	DI(3)
00060	DO(1)	DO(2)	DO(3)
00070	L(1)	L(2)	L(3)
00080	NM(1)	NM(2)	NM(3)
00090	X1G(1)	X1G(2)	X1G(3)
00100	X2L(1)	X2L(2)	X2L(3)
00110	X2T(1)	X2T(2)	X2T(3)
00120	DS(1)	DS(2)	DS(3)
00130	FHI(1)	FHI(2)	FHI(3)
00140	FHO(1)	FHO(2)	FHO(3)
00150	FNI(1)	FNI(2)	FNI(3)
00160	FNO(1)	FNO(2)	FNO(3)
00170	FTI(1)	FTI(2)	FTI(3)
00180	FTO(1)	FTO(2)	FTO(3)
00190	NMI(1)	NMI(2)	NMI(3)
00200	NMO(1)	NMO(2)	NMO(3)
00210	NSI(1)	NSI(2)	NSI(3)
00220	NSO(1)	NSO(2)	NSO(3)
00230	RM(1)	RM(2)	RM(3)
00240	TUBROW(1)	TUBROW(2)	TUBROW(3)
00250	NFSECT(I) for Vapor Generator		
	Following Data Refer to Condenser		
00260	BH(4)	BH(5)	BH(6)
00270	BT(4)	BT(5)	BT(6)

Figure 4. Arrangement of Data in Data Input File (Sheet 1 of 3)

Reference No.				
	Following Data Refer to Condenser (Cont'd)			
00280	DI(4)	DI(5)	DI(6)	
00290	DO(4)	DO(5)	DO(6)	
00300	L(4)	L(5)	L(6)	
00310	NM(4)	NM(5)	NM(6)	
00320	X1G(4)	X1G(5)	X1G(6)	
00330	X2L(4)	X2L(5)	X2L(6)	
00340	X2T(4)	X2T(5)	X2T(6)	
00350	DS(4)	DS(5)	DS(6)	
00360	FHI(4)	FHI(5)	FHI(6)	
00370	FHO(4)	FHO(5)	FHO(6)	
00380	FNI(4)	FNI(5)	FNI(6)	
00390	FNO(4)	FNO(5)	FNO(6)	
00400	FTI(4)	FTI(5)	FTI(6)	
00410	FTO(4)	FTO(5)	FTO(6)	
00420	NMI(4)	NMI(5)	NMI(6)	
00430	NMO(4)	NMO(5)	NMO(6)	
00440	NSI(4)	NSI(5)	NSI(6)	
00450	NSO(4)	NSO(5)	NSO(6)	
00460	RM(4)	RM(5)	RM(6)	
00470	TUBROW(4)	TUBROW(5)	TUBROW(6)	
00480	NFSECT(I) for Condenser			
	Following Data Refer to Regenerator			
00490	BH(7)	BH(8)	BH(9)	BH(10)
00500	BT(7)	BT(8)	BT(9)	BT(10)
00510	DI(7)	DI(8)	DI(9)	DI(10)
00520	DO(7)	DO(8)	DO(9)	DO(10)
00530	L(7)	L(8)	L(9)	L(10)
00540	NM(7)	NM(8)	NM(9)	NM(10)
00550	X1G(7)	X1G(8)	X1G(9)	X1G(10)

Figure 4. Arrangement of Data in Data Input File (Sheet 2 of 3)

Ref. No.	Following Data Refer to Regenerator (Cont'd)				
00560	X2L(7)	X2L(8)	X2L(9)	X2L(10)	
00570	X2T(7)	X2T(8)	X2T(9)	X2T(10)	
00580	DS(7)	DS(8)	DS(9)	DS(10)	
00590	FHI(7)	FHI(8)	FHI(9)	FHI(10)	
00600	FHO(7)	FHO(8)	FHO(9)	FHO(10)	
00610	FNI(7)	FNI(8)	FNI(9)	FNI(10)	
00620	FNO(7)	FNO(8)	FNO(9)	FNO(10)	
00630	FTI(7)	FTI(8)	FTI(9)	FTI(10)	
00640	FTO(7)	FTO(8)	FTO(9)	FTO(10)	
00650	NMI(7)	NMI(8)	NMI(9)	NMI(10)	
00660	NMO(7)	NMO(8)	NMO(9)	NMO(10)	
00670	NSI(7)	NSI(8)	NSI(9)	NSI(10)	
00680	NSO(7)	NSO(8)	NSO(9)	NSO(10)	
00690	RM(7)	RM(8)	RM(9)	RM(10)	
00700	TUBROW(7)	TUBROW(8)	TUBROW(9)	TUBROW(10)	
00710	NFSECT(I) for Regenerator				
	Design Data for Remaining Components				
00720	SP1	NP	AP		
00730	DISP	NPCYL			
00735	NBURNR				
00740	SSA	STA	STG		
00750	WS	WT	DCS	DCT	
00760	NBENDA	NBENDG			
00770	LHV	LCS	LCT		
00772	AF	CD	W	RADW	KO
00775	M				
	Following Data Are Read from TRANSM				
00780	R1L	RPM1L	R2L	RPM2L	GRL
00790	R1U	RPM1U	R2U	RPM2U	GRH
00800	GRRE				

Figure 4. Arrangement of Data in Data Input File (Sheet 3 of 3)

PROGRAM LISTING -- DATA INPUT

```
00010             3
00020             3           3            4
00030          .965          0.           0.
00040            .5          0.           0.
00050          .930        .930         .930
00060         1.315       1.315        1.315
00070           26.         17.          35.
00080             1           1            1
00090         1.315       1.315        1.315
00100          2.28        2.23         1.42
00110            0.
00120        .09375          0.           0.
00130            0.        .120           0.
00140            0.        .356           0.
00150            0.         16.           0.
00160            0.         10.           0.
00170            0.       .0312           0.
00180            0.        .012           0.
00190             0           1            0
00200             1           2            0
00210             1           2            1
00220             3           2            1
00230           .39          0.           0.
00240           5.5         5.9          8.9
00250             1
00260         1.515         .75         .765
00270          1.44         .72          .72
00280          .146        .146         .146
00290          .206        .206         .206
00300       4.16667     4.16667      4.16667
00310             1           1            1
00320         1.515         .75         .765
00330          .664        .664         .664
00340            0.          0.           0.
00350            0.          0.           0.
00360            0.          0.           0.
00370          .465        .465         .465
00380            0.          0.           0.
00390           14.         14.          14.
00400            0.          0.           0.
00410         .0025       .0025        .0025
00420             0
00430             2           2            2
00440             1           1            1
00450             2           2            2
00460            0.          0.           0.
00470            1.          1.           1.
00480            30
00490            .3          .3           .3           .3
00500           .29         .29          .29          .29
00510            .5          .5           .5           .5
00520          .550        .550         .550         .550
00530       8.33333     8.33333      8.33333      8.33333
00540             1           1            1            1
00550           .55         .55          .55          .55
00560           .85         .85          .85          .85
00570            0.
00580         .0625       .0625        .0625        .0625
00590            0.          0.           0.           0.
```

PROGRAM LISTING -- DATA INPUT (Cont'd)

```
00600          0.          0.          0.          0.
00610          0.          0.          0.          0.
00620          0.          0.          0.          0.
00630          0.          0.          0.          0.
00640          0.          0.          0.          0.
00650           1           1           1           1
00660           1           1           1           1
00670           1           1           1           1
00680           3           3           3           3
00690         .35         .35         .35         .35
00700          4.          4.          4.          4.
00710           4
00720          3.           4        15.3
00730        4.78           5
00735           2
00740        454.        374.        374.
00750         6.8        3.15          4.          7.
00760          75          30
00770      20180.        .708       1.415
00772         24.          .5       4600.          1.         .03
00775        11.9
00780       0.065        370.       0.065        435.          1.
00790         .26        550.        .155        660.        .584
00800        2.79
```

DATA FILE - DATA INITIAL

The Data Initial file 39 supplies all the system components with the initialization data required to start the program. Figure 5 indicates the arrangement of the data in Data Initial.

Reference No.					
00010	PWVI	HWVI	MWVI	MWVE	
00020	PWCI	HWCI	MWCI	MWCE	MGCI
00030	PWRI	HWRI	MWRI	MWRE	PGRI
00035	PWVE	PWCE			
	Following Data Refer to Vapor Generator				
00040	HFIN2(1)	HFIN1(2)	HFIN1(3)		
00050	HFIN2(1)	HFIN2(2)	HFIN2(3)		
00060	TGIN1(1)	TGIN1(2)	TGIN1(3)		
00070	TGIN2(1)	TGIN2(2)	TGIN2(3)		
	Following Data Refer to Condenser				
00100	HFIN1(4)	HFIN1(5)	HFIN1(6)		
00110	HFIN2(4)	HFIN2(5)	HFIN2(6)		
00120	TGIN1(4)	TGIN1(5)	TGIN1(6)		
00130	TGIN2(4)	TGIN2(5)	TGIN2(6)		
	Following Data Refer to Regenerator				
00160	HFIN1(7)	HFIN1(8)	HFIN1(9)	HFIN1(10)	
00170	HFIN2(7)	HFIN2(8)	HFIN2(9)	HFIN2(10)	
00200	HGIN1(7)	HGIN1(8)	HGIN1(9)	HGIN1(10)	
00210	HGIN2(7)	HGIN2(8)	HGIN2(9)	HGIN2(10)	
	Miscellaneous				
00280	FRAC				
00290	LINDEX	LINEX	LINBX		
	Initial Data for Remaining Components				
00300	MFUEL	MAIR	MFLUID	RFUEL	
00310	PO	TO			
00320	R	RPME			

Figure 5. Arrangement of Data in Data Initial File (Sheet 1 of 2)

Reference No.				
	Initial Data for Remaining Components (Cont'd)			
00330	RPUMP	RPMP		
00340	YEXT	TIME	TIMEX	DT
00350	IND	NND	NCYCLE	
00360	NPRINT	NSS	INE	NST
00370	AS	DIST	V	VT
00380	RPMX	CS		
00390	Z			

Figure 5. Arrangement of Data in Data Initial File (Sheet 2 of 2)

PROGRAM LISTING -- DATA INITIAL

```
00010             550.         -91.7          2.05          2.05
00020              25.           43.          2.05          2.05           17.
00030             550.         -124.          2.05          2.05           25.
00035             500.         24.55
00040            -91.7          -43.          25.8
00050             -43.          25.8         128.7
00060            1190.         3330.         1896.
00070             490.         1896.         1190.
00100              43.        -13.33        -69.66
00110           -13.33        -69.66         -126.
00120              85.        121.67        148.34
00130           121.67        148.34          175.
00160            -124.        -115.5         -107.         -98.5
00170           -115.5         -107.         -98.5          -90.
00200              77.          68.5           60.          51.5
00210             68.5           60.          51.5           43.
00280               .5
00290                0             0             0
00300            .0123         .2435          2.05         .0123
00310             14.7           85.
00320             .147         2000.
00330             .434         2000.
00340             900.            0.            0.            1.
00350                0             0             0
00360                1             1             0             0
00370               0.            0.            0.            0.
00380               0.            1.
00390                1
```

DATA FILE – ROUTE

The Route file 31 supplies the route profile for use in the DRIVER model.

PROGRAM LISTING -- ROUTE

Reference No.	LR (mi)	G	TI (sec)	AR (ft/ sec^2)	VR (mi/hr)	KF	CR
00010	.65	0.	1.	0.	0.	.5	0
00020	.65	0.	0.	10.	40.	.5	1
00030	.65	0.	0.	6.	50.	.5	1
00040	.65	0.	0.	3.	60.	.5	1
00050	.65	0.	0.	3.	60.	.5	0
00060	1.2	0.	0.	-5.	25.	.5	-1
00070	1.2	0.	0.	3.	25.	.5	0
00080	1.93	0.	0.	10.	40.	.5	1
00090	1.93	0.	0.	6.	50.	.5	1
00100	1.93	0.	0.	3.	70.	.5	1
00110	1.93	0.	0.	3.	70.	.5	0
00120	2.3	0.	0.	-10.	50.	.5	-1
00130	2.3	0.	0.	3.	50.	.5	0
00140	2.98	0.	0.	2.23	80.	.5	1
00150	2.98	0.	0.	-10.	50.	.5	-1
00160	2.98	0.	0.	3.	50.	.5	0
00170	3.65	0.	0.	-10.	0.	.5	-1
00180	3.65	0.	0.	8.8	65.	.5	1
00190	3.65	.05	0.	3.	65.	.5	0
00200	3.65	.05	0.	-10.	0.	.5	-1

Section 14

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Section 14

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APPENDIX I

Appendix I

WORKING FLUID THERMODYNAMIC PROPERTIES FOR CP-34, WATER, AND FC-75

The computer tabulations which make up this appendix present the thermodynamic properties of the three fluids under investigation:

- CP-34 -- Figures 6, 7, 8, and 9.
- Water -- Figures 10, 11, and 12.
- FC-75 -- Figures 13 and 14.

Table 3 lists their respective temperature and pressure ranges in both the saturated and the superheated states.

Table 3

RANGE OF FLUID PROPERTY TABULATIONS

Saturation				Superheat				
Fluid	Temperature Range	Number of Temperature Steps	Figure No.	Pressure Range	Temperature Range	Number of Pressure Steps	Number of Temperature Steps	Figure No.
CP-34	-55. 0°F to 580. 0°F	128	6	0. 1 psia to 600. 0 psia	175. 0°F to 600. 0°F	69	27	7,8,9
Water	150. 0°F to 550. 0°F	115	10	10. 0 psia to 1000. 0 psia	200. 0°F to 840. 0°F	41	33	11,12
FC-75	20. 0°C to 227. 06°C	25	13	0. 004 atm to 40. 0 atm	110. 0°C to 300. 0°C	35	20	14

The tabulations of the superheated fluid properties are interpreted in the following subsections.

FLUID: CP-34

The saturated fluid properties of CP-34 are listed in Figure 6.

The reading program for subroutine PROPST names the following four pressure values:

PTAB(1) = .1
PTAB(2) = .3
PTAB(3) = .5
PTAB(4) = 2.

These values together with those in the CP-34 superheated pressure and temperature tabulation (Figure 7) comprise the pressures and temperatures for which CP-34 superheated fluid properties are given in Figures 8 and 9.*

The first six lines of Figure 7 contain a total of 65 pressure values to be added to the previous list of four pressure values. Each pressure corresponds to a pressure block of 27 lines in Figure 8 or 9. (The last block of Figure 8 is repeated as the first block of Figure 9 to satisfy the interpolation program requirements.)

The remaining three lines of Figure 7 list 27 temperature values, corresponding to the 27 lines in every pressure block. Each line of a block in Figures 8 and 9 then gives the specific volume, enthalpy, entropy, and specific heat values that correspond to both the pressure for the block and the temperature for that particular line in the block.

For example, to find the CP-34 fluid properties that correspond to pressure 320.0 psia and temperature 480.0°F, first find 320.0 psia in Figure 7. It is the fifty-first pressure value in the tabulation. To fifty-one must be added the four pressure values named directly in subroutine PROPST. Since the total is then fifty-five, the fifty-fifth block of 27 lines in Figure 8 or 9 is then found.

Figure 8 contains only thirty-three pressure blocks; the thirty-third pressure block is repeated in Figure 9; therefore the twenty-third pressure block in Figure 9 corresponds to pressure 320.0 psia. The pressure blocks in Figures 8 and 9 have been sectioned off and labeled in order to facilitate this process. The temperature of 480.0°F is the fifteenth temperature, corresponding to the fifteenth line of the 320.0-psia pressure block, which gives the following values:

VTAB (51, 15) = 0.29749**
HTAB (51, 15) = 106.18000
STAB (51, 15) = 0.02190
CTAB (51, 15) = 0.37468

FLUID: WATER

Figure 10 is the computer tabulation of the saturated fluid properties of water.

---

*Figure 9 is a continuation of Figure 8. The listing was divided for computer storage purposes.

**The nomenclature and dimensions correspond to those used in the reading program of subroutine PROPST, listed in Volume II, page 6.

The reading of the superheated water property tabulation (Figure 12) is very much like that of the CP-34 listings. The pressure and temperature values, however, are read solely from Figure 11, and the specific volume, enthalpy, and specific heat are given in a single tabulation (Figure 12).

Each of the forty-one pressures in Figure 11 corresponds to a block of seventeen lines in Figure 12. The superheated tabulations for water vary from those for CP-34 in that each line of a pressure block in the water tables contains the fluid properties corresponding to the pressure value of that block and to two consecutive temperature values.

For example, find the water fluid properties that correspond to a pressure of 60.0 psia and a temperature of 420.0°F. Since 60.0 psia is the ninth pressure value in Figure 11, the ninth block of seventeen lines is located. The 420.0°F temperature is the twelfth temperature in Figure 11. Since each line of Figure 12 contains values corresponding to two consecutive temperature values, the values corresponding to the twelfth temperature are on the right-hand side of the sixth line of the pressure block. Thus, the fluid properties corresponding to pressure 60.0 psia and temperature of 420.0°F are:

VTAB (9,12) = 10.628
HTAB (9,12) = 1342.1
STAB (9,12) = 1.8260

FLUID: FC-75

The saturated fluid properties of FC-75 are given in Figure 13.

The reading of the superheated FC-75 fluid property tabulation (Figure 14) is almost identical with that of the water table. Each of the thirty-five pressure blocks is made up of ten lines, and each line contains the enthalpy, entropy, and specific volume values corresponding to two consecutive temperature values.

The significant difference between the listings for superheated water and FC-75 is that the pressure and temperature ranges are included as the first five lines of the FC-75 superheated fluid properties in Figure 14, instead of comprising a separate file. The finding of fluid properties to correspond to a given pressure and given temperature is identical with the process used for superheated water.

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P (psia)	T (°F)	VLIQ (ft^3/lb)	VVAP (ft^3/lb)	HLIQ (Btu/lb)	HVAP (Btu/lb)
0.01239	-55.00000	0.01412	4165.00000	-213.80000	-14.54000
0.01597	-50.00000	0.01416	3271.00000	-211.90000	-13.80000
0.02043	-45.00000	0.01420	2589.00000	-209.90000	-13.05000
0.02595	-40.00000	0.01423	2065.00000	-208.00000	-12.29000
0.03272	-35.00000	0.01427	1655.00000	-206.20000	-11.51000
0.04099	-30.00000	0.01431	1337.00000	-204.30000	-10.72000
0.05102	-25.00000	0.01435	1087.00000	-202.50000	-9.92000
0.06312	-20.00000	0.01439	888.30000	-200.70000	-9.11360
0.07764	-15.00000	0.01442	730.40000	-198.90000	-8.29100
0.09496	-10.00000	0.01446	603.80000	-197.10000	-7.46200
0.11550	-5.00000	0.01450	501.80000	-195.30000	-6.61900
0.13960	0.	0.01454	419.20000	-193.60000	-5.76300
0.16840	5.00000	0.01458	351.60000	-191.80000	-4.90000
0.20180	10.00000	0.01462	296.70000	-190.10000	-4.02400
0.24080	15.00000	0.01466	251.30000	-188.40000	-3.13000
0.28600	20.00000	0.01471	213.80000	-186.70000	-2.24000
0.33820	25.00000	0.01475	182.60000	-185.00000	-1.33000
0.39840	30.00000	0.01479	156.60000	-183.30000	-0.4166
0.46740	35.00000	0.01483	134.80000	-181.60000	0.51100
0.54630	40.00000	0.01487	116.50000	-179.90000	1.44900
0.63610	45.00000	0.01492	101.00000	-178.20000	2.39000
0.73810	50.00000	0.01496	87.88000	-176.50000	3.35300
0.85360	55.00000	0.01500	76.72000	-174.80000	4.32000
0.98380	60.00000	0.01505	67.19000	-173.20000	5.29700
1.13000	65.00000	0.01509	59.03000	-171.50000	6.28700
1.29500	70.00000	0.01514	52.01000	-169.80000	7.27700
1.47800	75.00000	0.01518	45.95000	-168.10000	8.28100
1.68300	80.00000	0.01523	40.72000	-166.50000	9.29300
1.91100	85.00000	0.01528	36.18000	-164.90000	10.32000
2.16400	90.00000	0.01532	32.22000	-163.10000	11.35000
2.44400	95.00000	0.01537	28.77000	-161.40000	12.38100
2.75300	100.00000	0.01542	25.76000	-159.70000	13.43000
3.09400	105.00000	0.01547	23.11000	-158.00000	14.48000
3.46900	110.00000	0.01552	20.78000	-156.30000	15.55000
3.88000	115.00000	0.01557	18.73000	-154.60000	16.62000
4.33000	120.00000	0.01562	16.92000	-152.90000	17.70000
4.82200	125.00000	0.01567	15.31000	-151.20000	18.78100
5.35800	130.00000	0.01572	13.88000	-149.50000	19.87000
5.94200	135.00000	0.01577	12.61000	-147.80000	20.97000
6.57600	140.00000	0.01582	11.48000	-146.10000	22.08000
7.26400	145.00000	0.01587	10.47000	-144.50000	23.19000
8.00900	150.00000	0.01593	9.56230	-142.50000	24.31000
8.81400	155.00000	0.01598	8.75090	-140.80000	25.43000
9.68200	160.00000	0.01603	8.01940	-139.00000	26.57000
10.62000	165.00000	0.01609	7.36230	-137.20000	27.70000
11.63000	170.00000	0.01615	6.76930	-135.40000	28.85000

Figure 6 . CP-34 Saturated Fluid Properties -- Pressure, Temperature, Specific Volume Liquid, Specific Volume Vapor, Enthalpy Liquid, and Enthalpy Vapor

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P (psia)	T (°F)	VLIQ (ft^3/lb)	VVAP (ft^3/lb)	HLIQ (Btu/lb)	HVAP (Btu/lb)
12.71000	175.00000	0.01620	6.23300	-133.60000	29.99000
13.87000	180.00000	0.01626	5.74700	-131.80000	31.15000
15.11000	185.00000	0.01632	5.30700	-130.00000	32.30000
16.44000	190.00000	0.01638	4.90800	-128.10000	33.47000
17.86000	195.00000	0.01643	4.54400	-126.30000	34.63000
19.37000	200.00000	0.01649	4.21300	-124.40000	35.81000
20.99000	205.00000	0.01656	3.91100	-122.50000	36.98000
22.70000	210.00000	0.01662	3.63500	-120.70000	38.16000
24.53000	215.00000	0.01668	3.38300	-118.80000	39.35000
26.47000	220.00000	0.01674	3.15100	-116.90000	40.53000
28.52000	225.00000	0.01681	2.93900	-115.00000	41.72000
30.70000	230.00000	0.01687	2.74400	-113.00000	42.92000
33.04000	235.00000	0.01694	2.56500	-111.10000	44.11000
35.44000	240.00000	0.01700	2.40000	-109.10000	45.31000
38.01000	245.00000	0.01707	2.24700	-107.10000	46.51000
40.72000	250.00000	0.01714	2.10700	-105.20000	47.72000
43.58000	255.00000	0.01721	1.97700	-103.20000	48.92000
46.59000	260.00000	0.01728	1.85700	-101.10000	50.13000
49.75000	265.00000	0.01735	1.74500	-99.12000	51.34000
53.08000	270.00000	0.01742	1.64200	-97.08000	52.55000
56.58000	275.00000	0.01750	1.54600	-95.02000	53.76000
60.24000	280.00000	0.01757	1.45700	-92.95000	54.97000
64.08000	285.00000	0.01765	1.37400	-90.86000	56.18000
68.11000	290.00000	0.01772	1.29700	-88.76000	57.40000
72.32000	295.00000	0.01780	1.22500	-86.65000	58.61000
76.73000	300.00000	0.01788	1.15800	-84.52000	59.82000
81.33000	305.00000	0.01796	1.09500	-82.38000	61.03000
86.13000	310.00000	0.01805	1.03700	-80.22000	62.24000
91.15000	315.00000	0.01813	0.98170	-78.04000	63.46000
96.38000	320.00000	0.01821	0.93040	-75.85000	64.66000
101.80000	325.00000	0.01830	0.88230	-73.65000	65.87000
107.50000	330.00000	0.01839	0.83730	-71.43000	67.08000
113.40000	335.00000	0.01848	0.79490	-69.19000	68.28000
119.50000	340.00000	0.01857	0.75520	-66.94000	69.48000
125.90000	345.00000	0.01866	0.71780	-64.68000	70.68000
132.50000	350.00000	0.01876	0.68270	-62.40000	71.88000
139.40000	355.00000	0.01886	0.64960	-60.10000	73.07000
146.50000	360.00000	0.01896	0.61840	-57.79000	74.26000
153.90000	365.00000	0.01906	0.58890	-55.46000	75.45000
161.60000	370.00000	0.01916	0.56120	-53.12000	76.63000
169.50000	375.00000	0.01927	0.53500	-50.76000	77.80000
177.70000	380.00000	0.01938	0.51020	-48.38000	78.98000
186.20000	385.00000	0.01949	0.48680	-45.99000	80.14000
195.00000	390.00000	0.01960	0.46460	-43.58000	81.30000
204.10000	395.00000	0.01972	0.44360	-41.16000	82.46000
213.40000	400.00000	0.01983	0.42370	-38.71000	83.61000
223.10000	405.00000	0.01996	0.40490	-36.26000	84.75000
233.10000	410.00000	0.02008	0.38700	-33.78000	85.88000

Figure 6 . CP-34 Saturated Fluid Properties (Cont'd)

P (psia)	T (°F)	VLIQ (ft^3/lb)	VVAP (ft^3/lb)	HLIQ (Btu/lb)	HVAP (Btu/lb)
243.40000	415.00000	0.02021	0.37000	-31.29000	87.01000
254.00000	420.00000	0.02034	0.35390	-28.73000	88.12000
264.90000	425.00000	0.02048	0.33850	-26.25000	89.23000
276.10000	430.00000	0.02062	0.32390	-23.71000	90.33000
287.70000	435.00000	0.02076	0.31000	-21.14000	91.42000
299.60000	440.00000	0.02091	0.29680	-18.56000	92.50000
311.90000	445.00000	0.02106	0.28420	-15.96000	93.57000
324.50000	450.00000	0.02122	0.27220	-13.34000	94.62000
337.40000	455.00000	0.02138	0.26070	-10.70000	95.66000
350.70000	460.00000	0.02155	0.24970	-8.03700	96.69000
364.40000	465.00000	0.02173	0.23920	-5.35600	97.71000
378.40000	470.00000	0.02191	0.22920	-2.65300	98.71000
392.80000	475.00000	0.02210	0.21960	0.07262	99.69000
407.60000	480.00000	0.02230	0.21050	2.82100	100.70000
422.70000	485.00000	0.02250	0.20170	5.59400	101.69000
438.20000	490.00000	0.02272	0.19320	8.39200	102.50000
454.10000	495.00000	0.02295	0.18510	11.22000	103.40000
470.40000	500.00000	0.02319	0.17740	14.07000	104.30000
487.10000	505.00000	0.02344	0.16990	16.95000	105.20000
504.10000	510.00000	0.02370	0.16270	19.87000	106.00000
521.60000	515.00000	0.02398	0.15580	22.81000	106.80000
539.40000	520.00000	0.02428	0.14910	25.80000	107.50000
557.70000	525.00000	0.02461	0.14260	28.82000	108.20000
576.40000	530.00000	0.02495	0.13640	31.83000	108.90000
595.90000	535.00000	0.02533	0.13010	31.49000	109.50000
616.40000	540.00000	0.02574	0.12380	34.62000	110.10000
637.50000	545.00000	0.02619	0.11750	37.87000	110.40000
659.10000	550.00000	0.02670	0.11140	41.23000	110.70000
681.40000	555.00000	0.02727	0.10530	44.73000	110.90000
704.20000	560.00000	0.02794	0.09929	48.52000	110.80000
727.70000	565.00000	0.02873	0.09318	52.53000	110.70000
751.80000	570.00000	0.02972	0.08869	56.93000	110.20000
776.50000	575.00000	0.03104	0.08026	61.93000	109.20000
802.00000	580.00000	0.03315	0.07279	68.16000	107.50000

Figure 6 . CP-34 Saturated Fluid Properties (Cont'd)

```
   3.0    5.0    7.0    9.0   11.0   13.0   15.0   17.0   19.0   21.0   23.0 ┐
  25.0   27.0   29.0   31.0   33.0   35.0   37.0   39.0   41.0   43.0   45.0 │
  47.0   49.0   50.0   60.0   70.0   80.0   90.0  100.0  110.0  120.0  130.0 │  PTAB(psia)
 140.0  150.0  160.0  170.0  180.0  190.0  200.0  210.0  220.0  230.0  240.0 │
 250.0  260.0  270.0  280.0  290.0  300.0  320.0  340.0  360.0  380.0  400.0 │
 420.0  440.0  460.0  480.0  500.0  520.0  540.0  560.0  580.0  600.0     0. ┘
 175.0  200.0  225.0  250.0  275.0  300.0  325.0  350.0  375.0  400.0  425.0 ┐
 450.0  460.0  470.0  480.0  490.0  500.0  510.0  520.0  530.0  540.0  550.0 │  TTAB(°F)
 560.0  570.0  580.0  590.0  600.0     0.     0.     0.     0.     0.     0. ┘
```

Figure 7 . CP-34 Superheated Fluid Properties -- Pressure and Temperature

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
809.49100	30.90740	.10924	.24416	0.1 psia
841.39000	37.12540	.11885	.25323	
873.29000	43.56650	.12843	.26201	
905.18900	50.22360	.13798	.27051	
937.08600	57.08940	.14748	.27871	
968.98300	64.15670	.15694	.28662	
1000.88000	71.41020	.16635	.29425	
1032.78000	78.86070	.17569	.30158	
1064.67000	86.49490	.18497	.30863	
1096.57000	94.29560	.19418	.31538	
1128.46000	102.26200	.20331	.32185	
1160.36000	110.38500	.21236	.32802	
1173.11800	113.72360	.21593	.33032	
1185.87600	117.06220	.21950	.33261	
1198.63400	120.40080	.22308	.33491	
1211.39200	123.73940	.22665	.33720	
1224.15000	127.07800	.23022	.33950	
1236.90600	130.52560	.23372	.34156	
1249.66200	133.97320	.23722	.34363	
1262.41800	137.42080	.24073	.34569	
1275.17400	140.86840	.24423	.34776	
1287.93000	144.31600	.24773	.34982	
1300.68800	147.86100	.25116	.35165	
1313.44600	151.40600	.25458	.35348	
1326.20400	154.95100	.25801	.35532	
1338.96200	158.49600	.26143	.35715	
1351.72000	162.04100	.26486	.35898	
269.73900	30.89320	.08328	.24419	0.3 psia
280.37900	37.11200	.09289	.25326	
291.01700	43.55400	.10248	.26204	
301.65500	50.21180	.11203	.27053	
312.29300	57.07830	.12153	.27874	
322.92900	64.14620	.13099	.28665	
333.56500	71.40830	.14048	.29427	
344.20100	78.85730	.14974	.30160	
354.83600	86.48590	.15902	.30864	
365.47100	94.28710	.16823	.31540	
376.10500	102.25300	.17736	.32186	
386.74000	110.37800	.18642	.32803	
390.99340	113.71660	.18999	.33033	
395.24680	117.05520	.19356	.33262	
399.50020	120.39380	.19714	.33492	
403.75360	123.73240	.20071	.33721	
408.00700	127.07100	.20428	.33951	
412.26040	130.51360	.20778	.34157	
416.51380	133.96620	.21128	.34364	
420.76720	137.41880	.21479	.34570	

Figure 8 . CP-34 Superheated Fluid Properties I -- Specific Volume, Enthalpy, Entropy, and Specific Heat

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
425.02060	140.66140	.21829	.34777	0.3 psia
429.27400	144.30906	.22179	.34983	
435.52720	147.85420	.22522	.35166	
441.78040	151.39940	.22864	.35349	
448.03360	154.94460	.23207	.35533	
454.28680	158.48979	.23549	.35716	
460.54000	162.03500	.23892	.35899	
161.78900	30.87900	.07121	.24423	0.5 psia
168.17600	37.09870	.08062	.25530	
174.56300	43.54150	.09040	.26207	
180.94900	50.20080	.09995	.27056	
187.33400	57.06720	.10946	.27870	
193.71800	64.13570	.11892	.28667	
200.10200	71.39630	.12833	.29429	
206.48600	78.84780	.13767	.30162	
212.86900	86.47700	.14695	.30860	
219.25200	94.27660	.15616	.31541	
225.63400	102.24500	.16530	.32188	
232.01600	110.37000	.17435	.32805	
234.56860	113.70880	.17792	.33034	
237.12120	117.04760	.18149	.33264	
239.67380	120.38640	.18507	.33493	
242.22640	123.72520	.18864	.33723	
244.77900	127.06400	.19221	.33952	
247.33160	130.51180	.19571	.34158	
249.88420	133.95960	.19921	.34365	
252.43680	137.40740	.20272	.34571	
254.98940	140.85520	.20622	.34778	
257.54200	144.30300	.20972	.34984	
260.09440	147.84820	.21315	.35167	
262.64680	151.39340	.21657	.35350	
265.19920	154.93859	.22000	.35534	
267.75159	158.48379	.22342	.35717	
270.30400	162.02900	.22685	.35900	
40.34450	30.77190	.03837	.24452	2.0 psia
41.94830	35.99950	.04799	.25356	
43.55130	43.44740	.05758	.26231	
45.15350	50.11160	.06714	.27078	
46.75510	56.98380	.07666	.27895	
48.35600	64.05690	.08612	.28685	
49.95640	71.32580	.09553	.29445	
51.55630	78.77720	.10488	.30177	
53.15590	86.40490	.11417	.30880	
54.75500	94.21480	.12338	.31554	
56.35380	102.18300	.13252	.32199	
57.95240	110.31200	.14158	.32816	
58.59164	113.65180	.14515	.33045	
59.23088	116.99160	.14872	.33274	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
59.87012	120.33140	.15230	.33504	2.0 psia
60.50936	123.67120	.15587	.33733	
61.14860	127.01100	.15944	.33962	
61.78768	130.46040	.16294	.34168	
62.42676	133.90980	.16645	.34374	
63.06584	137.35920	.16995	.34580	
63.70492	140.80860	.17346	.34786	
64.34400	144.25800	.17696	.34992	
64.98290	147.80320	.18039	.35175	
65.62180	151.34840	.18381	.35358	
66.26070	154.89359	.18724	.35541	
66.89960	158.43879	.19066	.35724	
67.53850	161.98400	.19409	.35907	
26.85000	30.70000	0.02872	0.24471	3.0 psia
27.92300	36.93100	0.03835	0.25373	
28.99400	43.38400	0.04795	0.26247	
30.06500	50.05200	0.05751	0.27092	
31.13500	56.92000	0.06703	0.27908	
32.20500	64.00400	0.07650	0.28697	
33.27300	71.27400	0.08592	0.29456	
34.34200	78.73000	0.09527	0.30187	
35.41000	86.36500	0.10456	0.30889	
36.47800	94.17200	0.11377	0.31563	
37.54500	102.14000	0.12291	0.32207	
38.61200	110.27000	0.13197	0.32823	
39.03900	113.57000	0.13558	0.33061	
39.46500	116.89000	0.13916	0.33295	
39.89200	120.23000	0.14274	0.33524	
40.31900	123.59000	0.14630	0.33748	
40.74500	126.98000	0.14985	0.33968	
41.17200	130.38000	0.15338	0.34183	
41.59800	133.81000	0.15690	0.34394	
42.02500	137.26000	0.16040	0.34600	
42.45100	140.73000	0.16389	0.34801	
42.87700	144.22000	0.16736	0.34998	
43.30400	147.73000	0.17082	0.35190	
43.73000	151.26000	0.17426	0.35377	
44.15700	154.81000	0.17769	0.35560	
44.58300	158.37000	0.18110	0.35738	
45.00900	161.95000	0.18450	0.35912	
16.05500	30.55600	0.01651	0.24511	5.0 psia
16.70200	36.79700	0.02615	0.25408	
17.34900	43.25800	0.03577	0.26278	
17.99400	49.93400	0.04534	0.27121	
18.63900	56.81600	0.05487	0.27935	
19.28300	63.89900	0.06435	0.28720	
19.92700	71.17400	0.07377	0.29478	
20.57000	78.63500	0.08313	0.30207	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
21.21300	86.27500	0.09242	0.30908	5.0 psia
21.85600	94.68700	0.10165	0.31588	
22.49800	102.06000	0.11079	0.32223	
23.13900	110.26000	0.11986	0.32838	
23.39600	113.49000	0.12346	0.33075	
23.65300	116.81000	0.12705	0.33309	
23.90900	120.15000	0.13062	0.33537	
24.16600	123.52000	0.13419	0.33761	
24.42200	126.91000	0.13773	0.33981	
24.67900	130.31000	0.14127	0.34196	
24.93500	133.74000	0.14479	0.34406	
25.19200	137.20000	0.14829	0.34611	
25.44800	140.67000	0.15178	0.34812	
25.70400	144.16000	0.15526	0.35009	
25.96100	147.67000	0.15872	0.35201	
26.21700	151.20000	0.16216	0.35388	
26.47300	154.75000	0.16559	0.35570	
26.72900	158.31000	0.16900	0.35748	
26.98500	161.89000	0.17240	0.35921	
11.42800	30.41100	0.00842	0.24551	7.0 psia
11.89300	36.66100	0.01808	0.25444	
12.35700	43.13100	0.02776	0.26311	
12.82100	49.81400	0.03729	0.27150	
13.28300	56.70400	0.04683	0.27961	
13.74600	63.79300	0.05631	0.28745	
14.20700	71.07400	0.06574	0.29500	
14.66800	78.54000	0.07511	0.30227	
15.12900	86.18300	0.08441	0.30926	
15.58900	94.00100	0.09363	0.31597	
16.04900	101.98000	0.10278	0.32239	
16.50800	110.12000	0.11185	0.32852	
16.69200	113.42000	0.11546	0.33090	
16.87600	116.74000	0.11905	0.33323	
17.06000	120.08000	0.12263	0.33551	
17.24300	123.45000	0.12619	0.33774	
17.42700	126.83000	0.12974	0.33993	
17.61000	130.24000	0.13327	0.34208	
17.79400	133.68000	0.13679	0.34418	
17.97700	137.13000	0.14030	0.34623	
18.16100	140.60000	0.14379	0.34824	
18.34400	144.09000	0.14727	0.35020	
18.52800	147.60000	0.15073	0.35211	
18.71100	151.13000	0.15417	0.35398	
18.89400	154.68000	0.15760	0.35581	
19.07800	158.25000	0.16102	0.35758	
19.26100	161.84000	0.16442	0.35931	
8.85750	30.26600	0.00234	0.24592	9.0 psia
9.22140	36.52500	0.01201	0.25481	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
9.58440	43.00400	0.02165	0.26343	9.0 psia
9.94660	49.69500	0.03124	0.27179	
10.30800	56.59100	0.04079	0.27988	
10.66900	63.68600	0.05029	0.28769	
11.02900	70.97300	0.05973	0.29522	
11.38900	78.44500	0.06910	0.30248	
11.74800	86.09500	0.07840	0.30945	
12.10700	93.91500	0.08763	0.31614	
12.46600	101.90000	0.09679	0.32255	
12.82400	110.04000	0.10586	0.32867	
12.96800	113.34000	0.10947	0.33104	
13.11100	116.66000	0.11306	0.33337	
13.25400	120.01000	0.11664	0.33564	
13.39700	123.37000	0.12020	0.33788	
13.54000	126.76000	0.12376	0.34006	
13.68300	130.17000	0.12729	0.34220	
13.82700	133.61000	0.13081	0.34430	
13.97000	137.06000	0.13432	0.34635	
14.11200	140.53000	0.13781	0.34835	
14.25500	144.03000	0.14129	0.35031	
14.39800	147.54000	0.14475	0.35222	
14.54100	151.07000	0.14820	0.35409	
14.68400	154.62000	0.15163	0.35591	
14.82700	158.19000	0.15504	0.35768	
14.97000	161.78000	0.15844	0.35941	
7.22140	30.11900	-0.00255	0.24633	11.0 psia
7.52100	36.38800	0.00713	0.25518	
7.81970	42.87600	0.01679	0.26377	
8.11750	49.57400	0.02639	0.27209	
8.41450	56.47800	0.03595	0.28015	
8.71160	63.58000	0.04546	0.28794	
9.00690	70.87200	0.05490	0.29545	
9.30230	78.35000	0.06428	0.30268	
9.59730	86.00400	0.07359	0.30964	
9.89190	93.82900	0.08283	0.31631	
10.18600	101.82000	0.09199	0.32271	
10.48000	109.96000	0.10107	0.32882	
10.59800	113.26000	0.10467	0.33119	
10.71500	116.59000	0.10827	0.33351	
10.83200	119.93000	0.11185	0.33578	
10.95000	123.30000	0.11542	0.33801	
11.06700	126.69000	0.11897	0.34019	
11.18500	130.11000	0.12250	0.34233	
11.30200	133.54000	0.12603	0.34442	
11.41900	136.99000	0.12954	0.34647	
11.53600	140.47000	0.13303	0.34847	
11.65300	143.96000	0.13651	0.35042	
11.77100	147.48000	0.13997	0.35233	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb°F)	CTAB (Btu/lb°F)	
11.88800	151.01000	0.14342	0.35419	11.0 psia
12.00500	154.56000	0.14685	0.35601	
12.12200	158.13000	0.15027	0.35778	
12.23900	161.72000	0.15367	0.35951	
0.01620	-133.61000	-0.26385	0.45490	13.0 psia
6.34370	36.25100	0.00305	0.25555	
6.59780	42.74700	0.01272	0.26410	
6.85110	49.45400	0.02234	0.27239	
7.10360	56.36400	0.03191	0.28042	
7.35550	63.47200	0.04142	0.28818	
7.60680	70.77100	0.05087	0.29567	
7.85760	78.25400	0.06026	0.30289	
8.10800	85.91300	0.06958	0.30983	
8.35810	93.74300	0.07882	0.31649	
8.60770	101.74000	0.08798	0.32287	
8.85710	109.88000	0.09706	0.32897	
8.95670	113.19000	0.10067	0.33133	
9.05640	116.51000	0.10427	0.33365	
9.15590	119.86000	0.10785	0.33592	
9.25550	123.23000	0.11142	0.33814	
9.35500	126.62000	0.11497	0.34032	
9.45440	130.04000	0.11851	0.34246	
9.55390	133.47000	0.12204	0.34454	
9.65330	136.93000	0.12555	0.34659	
9.75280	140.40000	0.12904	0.34858	
9.85200	143.90000	0.13252	0.35054	
9.95130	147.41000	0.13598	0.35244	
10.05100	150.95000	0.13943	0.35430	
10.15000	154.50000	0.14286	0.35612	
10.24900	158.07000	0.14628	0.35789	
10.34800	161.66000	0.14968	0.35961	
0.01620	-133.60000	-0.26385	0.45583	15.0 psia
5.49030	36.11200	-0.00046	0.25594	
5.70170	42.61700	0.00922	0.26444	
5.92230	49.33200	0.01865	0.27270	
6.14220	56.25000	0.02843	0.28070	
6.36140	63.36500	0.03795	0.28844	
6.58000	70.67000	0.04741	0.29590	
6.79820	78.15800	0.05680	0.30310	
7.01590	85.82200	0.06612	0.31002	
7.23320	93.65700	0.07537	0.31667	
7.45020	101.65000	0.08454	0.32304	
7.66680	109.81000	0.09363	0.32912	
7.75340	113.11000	0.09724	0.33148	
7.84060	116.44000	0.10084	0.33379	
7.92650	119.78000	0.10442	0.33606	
8.01290	123.16000	0.10799	0.33828	
8.09930	126.55000	0.11154	0.34045	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb°F)	CTAB (Btu/lb°F)	
8.18570	129.97000	0.11508	0.34258	15.0 psia
8.27210	133.40000	0.11861	0.34467	
8.35840	136.86000	0.12212	0.34671	
8.44470	140.34000	0.12562	0.34870	
8.53090	143.83000	0.12910	0.35065	
8.61710	147.35000	0.13256	0.35255	
8.70330	150.88000	0.13601	0.35441	
8.78950	154.44000	0.13944	0.35622	
8.87560	158.01000	0.14286	0.35799	
8.96170	161.60000	0.14627	0.35971	
0.01620	-133.60000	-0.26365	0.45373	17.0 psia
4.81990	35.97300	-0.00356	0.25632	
5.01640	42.48700	0.00614	0.26479	
5.21200	49.21000	0.01578	0.27301	
5.40690	56.13500	0.02537	0.28098	
5.60110	63.25700	0.03490	0.28869	
5.79480	70.56800	0.04437	0.29614	
5.98790	78.06100	0.05377	0.30331	
6.18070	85.73100	0.06310	0.31021	
6.37300	93.57000	0.07235	0.31685	
6.56500	101.57000	0.08152	0.32320	
6.75660	109.73000	0.09061	0.32927	
6.83320	113.03000	0.09423	0.33163	
6.90980	116.36000	0.09783	0.33393	
6.98620	119.71000	0.10141	0.33619	
7.06270	123.08000	0.10498	0.33841	
7.13910	126.48000	0.10854	0.34058	
7.21550	129.90000	0.11208	0.34271	
7.29190	133.33000	0.11561	0.34479	
7.36820	136.79000	0.11912	0.34683	
7.44440	140.27000	0.12261	0.34882	
7.52070	143.77000	0.12610	0.35076	
7.59640	147.2[illegible]000	0.12956	0.35266	
7.67310	150.82000	0.13301	0.35452	
7.74930	154.37000	0.13645	0.35633	
7.82540	157.95000	0.13987	0.35809	
7.90150	161.54000	0.14327	0.35981	
0.01620	-133.60000	-0.26385	0.45571	19.0 psia
4.29850	35.83200	-0.00632	0.25672	
4.47530	42.35600	0.00338	0.26514	
4.65120	49.08600	0.01304	0.27333	
4.82640	56.02000	0.02264	0.28127	
5.00090	63.14900	0.03218	0.28895	
5.17480	70.46600	0.04165	0.29637	
5.34830	77.96500	0.05106	0.30352	
5.52130	85.64000	0.06040	0.31041	
5.69390	93.48300	0.06966	0.31702	
5.86610	101.49000	0.07883	0.32336	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
6.03800	109.65000	0.08793	0.32943	19.0 psia
6.10670	112.95000	0.09154	0.33177	
6.17540	116.28000	0.09515	0.33408	
6.24400	119.64000	0.09873	0.33633	
6.31250	123.01000	0.10230	0.33855	
6.38110	126.41000	0.10586	0.34071	
6.44950	129.82000	0.10940	0.34284	
6.51800	133.26000	0.11293	0.34491	
6.58640	136.72000	0.11645	0.34695	
6.65480	140.20000	0.11994	0.34894	
6.72310	143.70000	0.12343	0.35088	
6.79150	147.22000	0.12689	0.35277	
6.85980	150.76000	0.13034	0.35463	
6.92800	154.31000	0.13378	0.35643	
6.99630	157.89000	0.13720	0.35819	
7.06450	161.48000	0.14061	0.35991	
0.01620	-133.60000	-0.26385	0.45667	21.0 psia
0.01649	-124.43000	-0.24970	0.45500	
4.03720	42.22500	0.00040	0.26550	
4.19720	48.96400	0.01056	0.27365	
4.35640	55.90500	0.02017	0.28155	
4.51560	63.04000	0.02972	0.28921	
4.67300	70.36300	0.03920	0.29660	
4.83040	77.86500	0.04862	0.30374	
4.98750	85.54800	0.05796	0.31061	
5.14410	93.39600	0.06722	0.31720	
5.30040	101.41000	0.07641	0.32353	
5.45630	109.57000	0.08551	0.32958	
5.51860	112.88000	0.08912	0.33192	
5.58090	116.21000	0.09273	0.33422	
5.64310	119.56000	0.09631	0.33647	
5.70520	122.94000	0.09989	0.33868	
5.76740	126.34000	0.10345	0.34085	
5.82960	129.75000	0.10699	0.34296	
5.89150	133.19000	0.11052	0.34504	
5.95360	136.66000	0.11404	0.34707	
6.01550	140.14000	0.11753	0.34905	
6.07750	143.64000	0.12102	0.35099	
6.13940	147.16000	0.12449	0.35289	
6.20130	150.69000	0.12794	0.35473	
6.26320	154.25000	0.13138	0.35654	
6.32500	157.82000	0.13480	0.35830	
6.38690	161.42000	0.13820	0.36001	
0.01620	-133.60000	-0.26385	0.45704	23.0 psia
0.01649	-124.43000	-0.24970	0.45469	
3.67520	42.09200	-0.00138	0.26586	
3.82200	48.84100	0.00830	0.27397	
3.96810	55.78400	0.01792	0.28184	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
4.11350	62.93100	0.02748	0.28947	23.0 psia
4.25830	70.26000	0.03697	0.29684	
4.40260	77.77100	0.04639	0.30395	
4.54650	85.45600	0.05574	0.31081	
4.68990	93.30900	0.06501	0.31739	
4.83300	101.32000	0.07420	0.32370	
4.97570	109.49000	0.08330	0.32973	
5.03270	112.80000	0.08692	0.33207	
5.08970	116.13000	0.09052	0.33437	
5.14670	119.49000	0.09411	0.33662	
5.20360	122.86000	0.09769	0.33882	
5.26040	126.26000	0.10125	0.34098	
5.31720	129.68000	0.10479	0.34309	
5.37400	133.13000	0.10832	0.34516	
5.43070	136.59000	0.11184	0.34719	
5.48750	140.07000	0.11534	0.34917	
5.54410	143.57000	0.11883	0.35111	
5.60080	147.09000	0.12230	0.35300	
5.65740	150.63000	0.12575	0.35484	
5.71400	154.19000	0.12919	0.35664	
5.77060	157.76000	0.13261	0.35840	
5.82710	161.36000	0.13602	0.36011	
0.01620	-133.60000	-0.26385	0.45707	25.0 psia
0.01649	-124.43000	-0.24971	0.45655	
3.37110	41.95900	-0.00348	0.26623	
3.50690	48.71600	0.00621	0.27430	
3.64190	55.67200	0.01585	0.28214	
3.77630	62.82100	0.02541	0.28973	
3.91000	70.15700	0.03491	0.29706	
4.04320	77.67300	0.04434	0.30417	
4.17600	85.36300	0.05370	0.31100	
4.30840	93.22100	0.06297	0.31757	
4.44040	101.24000	0.07217	0.32387	
4.57200	109.41000	0.08128	0.32989	
4.62460	112.72000	0.08489	0.33222	
4.67720	116.06000	0.08850	0.33451	
4.72970	119.41000	0.09209	0.33676	
4.78210	122.79000	0.09567	0.33896	
4.83450	126.19000	0.09923	0.34111	
4.88690	129.61000	0.10278	0.34322	
4.93930	133.05000	0.10631	0.34529	
4.99160	136.52000	0.10982	0.34731	
5.04390	140.00000	0.11333	0.34929	
5.09610	143.50000	0.11681	0.35122	
5.14830	147.03000	0.12028	0.35311	
5.20050	150.57000	0.12374	0.35495	
5.25270	154.13000	0.12718	0.35675	
5.30480	157.70000	0.13060	0.35850	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
5.35690	161.30000	0.13401	0.36021	25. 0 psia
0.01620	-133.60000	-0.26386	0.45821	27. 0 psia
0.01649	-124.43000	-0.24971	0.45615	
3.11200	41.82500	-0.00542	0.26660	
3.23840	48.59100	0.00428	0.27463	
3.36400	55.55500	0.01392	0.28244	
3.48890	62.71100	0.02350	0.29000	
3.61350	70.05300	0.03301	0.29732	
3.73710	77.57500	0.04244	0.30439	
3.86040	85.27100	0.05180	0.31121	
3.98350	93.13300	0.06109	0.31775	
4.10590	101.16000	0.07028	0.32404	
4.22810	109.33000	0.07940	0.33005	
4.27690	112.65000	0.08302	0.33238	
4.32570	115.98000	0.08663	0.33466	
4.37440	119.34000	0.09022	0.33690	
4.42310	122.72000	0.09380	0.33910	
4.47180	126.12000	0.09736	0.34125	
4.52040	129.54000	0.10091	0.34335	
4.56890	132.99000	0.10444	0.34542	
4.61750	136.45000	0.10796	0.34744	
4.66600	139.94000	0.11146	0.34941	
4.71440	143.44000	0.11495	0.35134	
4.76290	146.96000	0.11842	0.35322	
4.81130	150.50000	0.12188	0.35506	
4.85970	154.06000	0.12532	0.35686	
4.90800	157.64000	0.12874	0.35861	
4.95630	161.24000	0.13215	0.36031	
0.01620	-133.60000	-0.26386	0.45840	29. 0 psia
0.01649	-124.43000	-0.24971	0.45630	
0.01681	-114.96000	-0.23565	0.45561	
3.01690	46.46600	0.00248	0.27497	
3.12440	55.43700	0.01213	0.28274	
3.24120	62.60100	0.02172	0.29027	
3.35740	69.94900	0.03123	0.29757	
3.47310	77.47700	0.04068	0.30462	
3.58830	85.17300	0.05004	0.31141	
3.70310	93.04500	0.05933	0.31794	
3.81760	101.07000	0.06853	0.32421	
3.93170	109.25000	0.07765	0.33020	
3.97720	112.57000	0.08128	0.33253	
4.02270	115.90000	0.08488	0.33481	
4.06820	119.26000	0.08848	0.33704	
4.11360	122.64000	0.09206	0.33924	
4.15900	126.05000	0.09562	0.34138	
4.20440	129.47000	0.09917	0.34349	
4.24970	132.92000	0.10271	0.34554	
4.29500	136.38000	0.10623	0.34756	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
4.34020	139.87000	0.10973	0.34953	29.0 psia
4.38540	143.37000	0.11322	0.35146	
4.43060	146.90000	0.11669	0.35334	
4.47570	150.44000	0.12015	0.35517	
4.52090	154.00000	0.12359	0.35697	
4.56600	157.58000	0.12702	0.35871	
4.61100	161.17000	0.13042	0.36041	
0.01620	-133.60000	-0.26386	0.45911	31.0 psia
0.01649	-124.43000	-0.24971	0.45549	
0.01681	-114.95000	-0.23565	0.45571	
2.80520	45.34000	0.00078	0.27531	
2.91570	55.31900	0.01045	0.28304	
3.02550	62.49000	0.02005	0.29055	
3.13460	69.84500	0.02957	0.29782	
3.24320	77.37900	0.03902	0.30484	
3.35130	85.08500	0.04839	0.31161	
3.45910	92.95700	0.05769	0.31813	
3.56640	100.99000	0.06690	0.32438	
3.67340	109.17000	0.07602	0.33036	
3.71620	112.49000	0.07964	0.33268	
3.75880	115.83000	0.08325	0.33496	
3.80150	119.19000	0.08685	0.33719	
3.84410	122.57000	0.09043	0.33938	
3.88660	125.98000	0.09400	0.34152	
3.92910	129.40000	0.09755	0.34362	
3.97160	132.85000	0.10108	0.34567	
4.01410	136.31000	0.10460	0.34768	
4.05650	139.80900	0.10811	0.34965	
4.09880	143.31000	0.11160	0.35157	
4.14120	146.83000	0.11507	0.35345	
4.18350	150.38000	0.11853	0.35528	
4.22580	153.94000	0.12197	0.35707	
4.26800	157.52000	0.12540	0.35882	
4.31030	161.11000	0.12881	0.36052	
0.01620	-133.60000	-0.26386	0.46054	33.0 psia
0.01649	-124.42000	-0.24971	0.45680	
0.01680	-114.95000	-0.23565	0.45670	
2.62800	46.21300	-0.00081	0.27566	
2.73220	55.20100	0.00887	0.28335	
2.83580	62.37300	0.01847	0.29082	
2.93870	69.74000	0.02801	0.29807	
3.04110	77.28000	0.03746	0.30507	
3.14310	84.99200	0.04654	0.31182	
3.24460	92.86900	0.05614	0.31832	
3.34570	100.91000	0.06536	0.32455	
3.44650	109.09000	0.07448	0.33052	
3.48670	112.41000	0.07811	0.33284	
3.52690	115.75000	0.08172	0.33511	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
3.56710	119.11000	0.08532	0.33733	33.0 psia
3.60720	122.50000	0.08890	0.33951	
3.64720	125.90000	0.09247	0.34165	
3.68730	129.33000	0.09602	0.34375	
3.72720	132.78000	0.09956	0.34580	
3.76720	136.25000	0.10308	0.34781	
3.80710	139.73000	0.10659	0.34977	
3.84700	143.24000	0.11008	0.35169	
3.88690	146.77000	0.11355	0.35357	
3.92670	150.31000	0.11701	0.35540	
3.96650	153.88000	0.12046	0.35718	
4.00620	157.46000	0.12388	0.35892	
4.04600	[illegible]	0.12729	0.36062	
0.01620	-133.60000	-0.26386	0.45908	35.0 psia
0.01649	-124.42000	-0.24971	0.45751	
0.01680	-114.95000	-0.23566	0.45555	
2.47090	47.08500	-0.00232	0.27601	
2.56970	55.08200	0.00737	0.28366	
2.66780	62.26700	0.01699	0.29111	
2.76530	69.63500	0.02653	0.29832	
2.86220	77.18100	0.03599	0.30530	
2.95860	84.69800	0.04538	0.31203	
3.05460	92.78000	0.05468	0.31851	
3.15020	100.82000	0.06390	0.32473	
3.24550	108.61000	0.07303	0.33066	
3.28350	112.35000	0.07666	0.33299	
3.32150	115.67000	0.08028	0.33526	
3.35940	119.04000	0.08387	0.33748	
3.39730	122.42000	0.08746	0.33966	
3.43520	125.83000	0.09103	0.34179	
3.47300	129.26000	0.09458	0.34388	
3.51080	132.71000	0.09812	0.34593	
3.54850	136.18000	0.10164	0.34793	
3.58630	139.67000	0.10515	0.34990	
3.62390	143.18000	0.10864	0.35181	
3.66160	146.70000	0.11212	0.35368	
3.69920	150.25000	0.11558	0.35551	
3.73680	153.81000	0.11903	0.35729	
3.77430	157.39000	0.12245	0.35903	
3.81190	160.99000	0.12587	0.36072	
0.01620	-133.60000	-0.26386	0.45921	37.0 psia
0.01649	-124.42000	-0.24971	0.45906	
0.01680	-114.95000	-0.23566	0.45701	
2.33080	47.95700	-0.00375	0.27637	
2.42480	54.96200	0.00595	0.28398	
2.51800	62.15400	0.01557	0.29139	
2.61050	69.52900	0.02512	0.29858	
2.70250	77.08100	0.03460	0.30553	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb°F)	CTAB (Btu/lb°F)	
2.79400	84.80400	0.04399	0.31224	37. 0 psia
2.88510	92.69100	0.05330	0.31870	
2.97580	100.74000	0.06253	0.32490	
3.06620	108.93000	0.07166	0.33084	
3.10230	112.25000	0.07529	0.33315	
3.13830	115.60000	0.07891	0.33541	
3.17430	118.96000	0.08251	0.33762	
3.21020	122.35000	0.08609	0.33980	
3.24610	125.76000	0.08966	0.34193	
3.28190	129.19000	0.09322	0.34402	
3.31770	132.64000	0.09676	0.34606	
3.35350	136.11000	0.10028	0.34806	
3.38930	139.60000	0.10379	0.35002	
3.42500	143.11000	0.10729	0.35193	
3.46070	146.64000	0.11076	0.35380	
3.49630	150.18000	0.11423	0.35562	
3.53190	153.75000	0.11767	0.35740	
3.56750	157.33000	0.12110	0.35914	
3.60310	160.93000	0.12451	0.36083	
0.01620	-133.59000	-0.26386	0.46153	39. 0 psia
0.01649	-124.42000	-0.24971	0.45909	
0.01680	-114.95000	-0.23566	0.45766	
2.20510	47.82500	-0.00512	0.27673	
2.29460	54.84100	0.00460	0.28431	
2.38350	62.04200	0.01423	0.29168	
2.47160	69.42400	0.02379	0.29884	
2.55920	76.98200	0.03327	0.30576	
2.64630	84.71000	0.04267	0.31245	
2.73300	92.60200	0.05190	0.31889	
2.81930	100.65000	0.06122	0.32508	
2.90530	108.85000	0.07036	0.33101	
2.93960	112.18000	0.07399	0.33330	
2.97390	115.52000	0.07761	0.33556	
3.00810	118.89000	0.08121	0.33777	
3.04220	122.28000	0.08480	0.33994	
3.07640	125.69000	0.08837	0.34207	
3.11040	129.12000	0.09193	0.34415	
3.14450	132.57000	0.09547	0.34619	
3.17850	136.04000	0.09899	0.34819	
3.21250	139.53000	0.10250	0.35014	
3.24640	143.04000	0.10600	0.35205	
3.28030	146.57000	0.10948	0.35391	
3.31420	150.12000	0.11294	0.35573	
3.34810	153.69000	0.11639	0.35751	
3.38190	157.27000	0.11982	0.35924	
3.41570	160.87000	0.12323	0.36093	
0.01620	-133.59000	-0.26386	0.46137	41. 0 psia
0.01649	-124.42000	-0.24971	0.45903	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb°F)	CTAB (Btu/lb°F)	
0.01680	-114.95000	-0.23566	0.45910	41.0 psia
0.01714	-105.16000	-0.22165	0.45761	
2.17720	54.72100	0.00336	0.28463	
2.26200	61.92900	0.01295	0.29197	
2.34630	69.31700	0.02252	0.29910	
2.42990	76.88100	0.03251	0.30600	
2.51310	84.61500	0.04132	0.31260	
2.59580	92.51300	0.05074	0.31909	
2.67810	100.57000	0.05997	0.32526	
2.76010	108.77000	0.06912	0.33117	
2.79260	112.10000	0.07275	0.33346	
2.82550	115.44000	0.07637	0.33571	
2.85810	118.81000	0.07997	0.33792	
2.89060	122.20000	0.08356	0.34009	
2.92320	125.61000	0.08714	0.34221	
2.95570	129.04000	0.09070	0.34429	
2.98810	132.50000	0.09424	0.34632	
3.02060	135.97000	0.09776	0.34831	
3.05290	139.46000	0.10128	0.35026	
3.08530	142.98000	0.10477	0.35217	
3.11760	146.51000	0.10826	0.35403	
3.14990	150.06000	0.11172	0.35585	
3.18220	153.62000	0.11516	0.35762	
3.21440	157.21000	0.11860	0.35935	
3.24660	160.81000	0.12201	0.36105	
0.01620	-133.59000	-0.26347	0.46301	43.0 psia
0.01649	-124.42000	-0.24972	0.46045	
0.01680	-114.95000	-0.23566	0.45871	
0.01714	-105.16000	-0.22165	0.45749	
2.07060	54.59900	0.00267	0.28496	
2.15190	61.81500	0.01173	0.29226	
2.23250	69.21100	0.02130	0.29936	
2.31260	76.78100	0.03140	0.30623	
2.39210	84.52100	0.04022	0.31288	
2.47130	92.42300	0.04954	0.31923	
2.55000	100.48000	0.05878	0.32544	
2.62840	108.69000	0.06794	0.33134	
2.65960	112.02000	0.07157	0.33362	
2.69090	115.37000	0.07519	0.33587	
2.72200	118.73000	0.07879	0.33807	
2.75320	122.13000	0.08239	0.34023	
2.78430	125.54000	0.08596	0.34235	
2.81530	128.97000	0.08952	0.34442	
2.84630	132.43000	0.09306	0.34645	
2.87730	135.90000	0.09659	0.34844	
2.90820	139.40000	0.10011	0.35039	
2.93910	142.91000	0.10360	0.35229	
2.97000	146.44000	0.10708	0.35415	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
3.00090	149.99000	0.11055	0.35596	43. 0 psia
3.03170	153.56000	0.11406	0.35773	
3.06250	157.15000	0.11743	0.35945	
3.09320	160.75000	0.12085	0.36114	
0.01620	-133.59000	-0.26386	0.46314	45. 0 psia
0.01649	-124.42000	-0.24972	0.45958	
0.01680	-114.95000	-0.23566	0.45896	
0.01714	-105.16000	-0.22166	0.45745	
1.97350	51.47700	0.00059	0.28530	
2.05160	61.70100	0.01055	0.29256	
2.12890	69.10400	0.02014	0.29963	
2.20570	76.68000	0.02964	0.30647	
2.28200	84.42600	0.03907	0.31310	
2.35780	92.33500	0.04840	0.31948	
2.43330	100.40000	0.05765	0.32562	
2.50840	108.61000	0.06680	0.33159	
2.53830	111.94000	0.07044	0.33378	
2.56820	115.29000	0.07406	0.33602	
2.59810	118.66000	0.07767	0.33822	
2.62790	122.05000	0.08126	0.34038	
2.65770	125.47000	0.08484	0.34249	
2.68740	128.90000	0.08840	0.34456	
2.71710	132.36000	0.09194	0.34659	
2.74680	135.83900	0.09547	0.34857	
2.77640	139.33000	0.09899	0.35051	
2.80600	142.84000	0.10248	0.35241	
2.83550	146.38000	0.10597	0.35426	
2.86510	149.93000	0.10943	0.35608	
2.89460	153.50000	0.11288	0.35784	
2.92400	157.09000	0.11632	0.35957	
2.95350	160.69000	0.11973	0.36124	
0.01620	-133.59000	-0.26347	0.46394	47. 0 psia
0.01649	-124.42000	-0.24972	0.46156	
0.01680	-114.95000	-0.23566	0.45936	
0.01714	-105.16000	-0.22166	0.45888	
1.88470	54.35500	-0.00025	0.28564	
1.95970	61.58600	0.00943	0.29286	
2.03410	68.99600	0.01902	0.29990	
2.10790	76.57900	0.02853	0.30672	
2.18120	84.33000	0.03796	0.31332	
2.25400	92.24300	0.04730	0.31968	
2.32650	100.31000	0.05655	0.32580	
2.39860	108.53000	0.06571	0.33167	
2.42730	111.86000	0.06935	0.33394	
2.45600	115.21000	0.07298	0.33618	
2.48470	118.58000	0.07659	0.33837	
2.51330	121.98000	0.08018	0.34052	
2.54190	125.39000	0.08376	0.34263	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
2.57040	128.83000	0.08732	0.34470	47.0 psia
2.59890	132.29000	0.09067	0.34672	
2.62730	135.76000	0.09440	0.34870	
2.65580	139.26000	0.09791	0.35064	
2.68410	142.78000	0.10141	0.35253	
2.71250	146.31000	0.10490	0.35438	
2.74080	149.86000	0.10836	0.35619	
2.76910	153.43000	0.11181	0.35796	
2.79740	157.02000	0.11525	0.35968	
2.82560	160.63000	0.11867	0.36135	
0.01620	-133.59000	-0.26337	0.46366	49.0 psia
0.01649	-124.42000	-0.24972	0.46184	
0.01680	-114.95000	-0.23566	0.46010	
0.01714	-105.16000	-0.22166	0.45897	
1.80300	54.23100	-0.00135	0.28598	
1.87540	61.47100	0.00834	0.29317	
1.94700	68.88400	0.01794	0.30017	
2.01810	76.47300	0.02747	0.30696	
2.08860	84.23500	0.03690	0.31354	
2.15870	92.15300	0.04625	0.31988	
2.22840	100.23000	0.05550	0.32598	
2.29770	108.45000	0.06467	0.33184	
2.32540	111.78000	0.06831	0.33411	
2.35300	115.13000	0.07193	0.33633	
2.38050	118.51000	0.07555	0.33852	
2.40800	121.90000	0.07914	0.34067	
2.43550	125.32000	0.08272	0.34277	
2.46290	128.76000	0.08628	0.34483	
2.49030	132.22000	0.08983	0.34685	
2.51770	135.69000	0.09336	0.34883	
2.54500	139.19000	0.09688	0.35077	
2.57220	142.71000	0.10038	0.35265	
2.59950	146.25000	0.10387	0.35450	
2.62670	149.80000	0.10734	0.35631	
2.65390	153.37000	0.11079	0.35807	
2.68110	156.96000	0.11422	0.35978	
2.70820	160.57000	0.11764	0.36146	
0.01620	-133.59000	-0.26387	0.46428	50.0 psia
0.01649	-124.42000	-0.24972	0.46187	
0.01680	-114.95000	-0.23566	0.45992	
0.01714	-105.16000	-0.22166	0.45906	
1.76470	54.17000	-0.00188	0.28615	
1.83570	61.41300	0.00781	0.29332	
1.90610	68.83400	0.01742	0.30031	
1.97580	76.42700	0.02695	0.30709	
2.04510	84.18700	0.03639	0.31365	
2.11390	92.10600	0.04573	0.31998	
2.18230	100.18000	0.05499	0.32607	

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Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
2.25030	108.41000	0.06416	0.33192	50. 0 psia
2.27740	111.74000	0.06780	0.33419	
2.30450	115.09000	0.07143	0.33641	
2.33160	118.47000	0.07504	0.33860	
2.35850	121.86000	0.07864	0.34074	
2.38550	125.28000	0.08222	0.34284	
2.41240	128.72000	0.08578	0.34490	
2.43930	132.18000	0.08933	0.34692	
2.46610	135.66000	0.09286	0.34889	
2.49290	139.16000	0.09638	0.35083	
2.51970	142.68000	0.09988	0.35272	
2.54640	146.21000	0.10337	0.35456	
2.57310	149.77000	0.10684	0.35636	
2.59980	153.34000	0.11029	0.35813	
2.62640	156.93000	0.11373	0.35984	
2.65300	160.54000	0.11715	0.36151	
0.01620	-133.59000	-0.26387	0.46707	60. 0 psia
0.01649	-124.41000	-0.24972	0.46317	
0.01680	-114.94000	-0.23567	0.46258	
0.01714	-105.15000	-0.22167	0.46126	
0.01750	-95.01700	-0.20768	0.46003	
1.51170	60.82900	0.00299	0.29492	
1.57160	68.28700	0.01265	0.30172	
1.63080	75.91400	0.02221	0.30835	
1.68960	83.70400	0.03169	0.31479	
1.74780	91.65200	0.04107	0.32101	
1.80570	99.75200	0.05036	0.32701	
1.86310	108.00000	0.05955	0.33278	
1.88600	111.34000	0.06320	0.33502	
1.90890	114.70000	0.06684	0.33721	
1.93170	118.08000	0.07046	0.33938	
1.95440	121.49000	0.07406	0.34149	
1.97720	124.91000	0.07765	0.34357	
1.99980	128.36000	0.08122	0.34560	
2.02250	131.83000	0.08478	0.34760	
2.04510	135.31000	0.08832	0.34955	
2.06760	138.82000	0.09184	0.35147	
2.09010	142.34000	0.09535	0.35334	
2.11260	145.88000	0.09884	0.35516	
2.13510	149.44000	0.10231	0.35695	
2.15750	153.02000	0.10577	0.35869	
2.17990	156.62000	0.10921	0.36039	
2.20230	160.23000	0.11264	0.36205	
0.01620	-133.58000	-0.26388	0.46852	70. 0 psia
0.01649	-124.41000	-0.24973	0.46658	
0.01680	-114.94000	-0.23568	0.46524	
0.01714	-105.15000	-0.22167	0.46151	
0.01750	-95.01200	-0.20769	0.46216	

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Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
1.27980	60.23000	-0.00118	0.29662	70. 0 psia
1.33230	67.73000	0.00853	0.30323	
1.38420	75.39000	0.01814	0.30969	
1.43540	83.21000	0.02765	0.31599	
1.48620	91.18000	0.03705	0.32209	
1.53650	99.31000	0.04638	0.32799	
1.58650	107.59000	0.05560	0.33367	
1.60640	110.93000	0.05926	0.33588	
1.62620	114.30000	0.06291	0.33804	
1.64600	117.70000	0.06653	0.34017	
1.66570	121.11000	0.07015	0.34226	
1.68540	124.54000	0.07374	0.34432	
1.70510	127.99000	0.07732	0.34633	
1.72470	131.47000	0.08088	0.34830	
1.74420	134.96000	0.08443	0.35023	
1.76380	138.47000	0.08796	0.35212	
1.78330	142.00000	0.09148	0.35397	
1.80270	145.55000	0.09498	0.35578	
1.82220	149.12000	0.09845	0.35755	
1.84160	152.70000	0.10192	0.35927	
1.86090	156.30000	0.10537	0.36096	
1.88030	159.92000	0.10880	0.36259	
0.01620	-133.58000	-0.26388	0.47174	80. 0 psia
0.01649	-124.40000	-0.24974	0.46800	
0.01680	-114.94000	-0.23568	0.46499	
0.01714	-105.15000	-0.22168	0.46324	
0.01749	-95.00000	-0.20770	0.46331	
0.01788	-84.51700	-0.19372	0.46516	
1.15270	67.16000	0.00468	0.30482	
1.19960	74.65000	0.01454	0.31110	
1.24470	82.71000	0.02409	0.31724	
1.28960	90.72000	0.03354	0.32321	
1.33460	98.87000	0.04289	0.32900	
1.37890	107.17000	0.05214	0.33459	
1.39650	110.52000	0.05581	0.33676	
1.41410	113.90000	0.05946	0.33890	
1.43160	117.30000	0.06309	0.34100	
1.44910	120.72000	0.06672	0.34306	
1.46650	124.16000	0.07032	0.34508	
1.48390	127.62000	0.07391	0.34707	
1.50130	131.11000	0.07748	0.34902	
1.51860	134.60000	0.08103	0.35092	
1.53580	138.12000	0.08457	0.35279	
1.55310	141.66000	0.08809	0.35462	
1.57030	145.22000	0.09159	0.35641	
1.58740	148.79000	0.09508	0.35816	
1.60460	152.38000	0.09855	0.35987	
1.62170	155.99000	0.10200	0.36153	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
1.63870	159.61000	0.10544	0.36315	80. 0 psia
0.01620	-133.57000	-0.26389	0.47512	90. 0 psia
0.01649	-124.40000	-0.24974	0.37932	
0.01680	-114.93000	-0.23569	0.38978	
0.01714	-105.14000	-0.22169	0.40647	
0.01749	-95.00600	-0.20771	0.42047	
0.01788	-84.51500	-0.19373	0.46562	
1.01270	66.57000	0.00159	0.30651	
1.05470	74.31700	0.01130	0.31258	
1.09610	82.20600	0.02089	0.31856	
1.13700	90.24300	0.03038	0.32439	
1.17740	98.42400	0.03976	0.33006	
1.21730	106.74000	0.04903	0.33554	
1.23320	110.11000	0.05272	0.33767	
1.24900	113.50000	0.05638	0.33978	
1.26480	116.91000	0.06002	0.34185	
1.28050	120.33000	0.06365	0.34388	
1.29620	123.78000	0.06727	0.34587	
1.31190	127.25000	0.07086	0.34783	
1.32740	130.74000	0.07444	0.34975	
1.34300	134.25000	0.07800	0.35164	
1.35850	137.77000	0.08155	0.35348	
1.37400	141.32000	0.08507	0.35529	
1.38940	144.88000	0.08858	0.35706	
1.40480	148.46000	0.09208	0.35876	
1.42020	152.05000	0.09555	0.36047	
1.43550	155.67000	0.09901	0.36212	
1.45080	159.30000	0.10245	0.36372	
0.01620	-133.57000	-0.26390	0.36498	100. 0 psia
0.01649	-124.40000	-0.24975	0.37443	
0.01680	-114.93000	-0.23570	0.38764	
0.01714	-105.14000	-0.22169	0.40152	
0.01749	-95.00300	-0.20771	0.41889	
0.01788	-84.51200	-0.19374	0.43578	
0.90046	65.98200	-0.00142	0.30833	
0.93914	73.76300	0.00834	0.31416	
0.97714	81.69400	0.01798	0.31994	
1.01460	89.76000	0.02751	0.32562	
1.05150	97.97000	0.03692	0.33115	
1.08800	106.32000	0.04622	0.33653	
1.10250	109.69000	0.04991	0.33862	
1.11690	113.09000	0.05359	0.34069	
1.13130	116.51000	0.05724	0.34273	
1.14560	119.94000	0.06088	0.34473	
1.15990	123.40000	0.06450	0.34669	
1.17420	126.88000	0.06811	0.34861	
1.18830	130.37000	0.07169	0.35051	
1.20250	133.89000	0.07526	0.35237	

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Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
1.21660	137.42000	0.07881	0.35419	100. 0 psia
1.23070	140.97000	0.08235	0.35597	
1.24470	144.54000	0.08586	0.35772	
1.25870	148.12000	0.08936	0.35942	
1.27270	151.73000	0.09285	0.36110	
1.28660	155.35000	0.09631	0.36272	
1.30050	158.98000	0.09976	0.36431	
0.01620	-133.56000	-0.26340	0.36021	110. 0 psia
0.01649	-124.39000	-0.24976	0.37043	
0.01680	-114.92000	-0.23570	0.38442	
0.01714	-105.13000	-0.22170	0.39852	
0.01749	-95.00100	-0.20772	0.41650	
0.01788	-84.50900	-0.19375	0.43324	
0.01830	-73.64760	-0.17976	0.46972	
0.84438	73.19400	0.00561	0.31583	
0.87964	81.16400	0.01536	0.32140	
0.91429	89.26000	0.02426	0.32690	
0.94841	97.50000	0.03431	0.33230	
0.98209	105.88000	0.04364	0.33756	
0.99545	109.27000	0.04734	0.33961	
1.00880	112.67000	0.05103	0.34163	
1.02200	116.10000	0.05459	0.34363	
1.03520	119.55000	0.05834	0.34559	
1.04830	123.01000	0.06197	0.34752	
1.06140	126.50000	0.06558	0.34942	
1.07450	130.00000	0.06918	0.35129	
1.08750	133.52000	0.07276	0.35312	
1.10040	137.06000	0.07631	0.35492	
1.11340	140.62000	0.07986	0.35668	
1.12630	144.20000	0.08338	0.35840	
1.13910	147.79000	0.08689	0.36008	
1.15190	151.40000	0.09037	0.36173	
1.16470	155.02000	0.09384	0.36334	
1.17740	158.66000	0.09730	0.36490	
0.01620	-133.56000	-0.26341	0.35548	120. 0 psia
0.01649	-124.39000	-0.24976	0.36542	
0.01680	-114.92000	-0.23571	0.37888	
0.01713	-105.13000	-0.22171	0.39583	
0.01749	-94.99000	-0.20773	0.41322	
0.01788	-84.50700	-0.19375	0.43176	
0.01830	-73.64400	-0.17977	0.44922	
0.76524	72.62100	0.00346	0.31762	
0.79825	81.62000	0.01279	0.32295	
0.83060	89.76000	0.02240	0.32825	
0.86242	97.94000	0.03149	0.33349	
0.89376	105.44000	0.04125	0.33862	
0.90619	108.84000	0.04497	0.34063	
0.91855	112.25000	0.04866	0.34261	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.93085	115.69000	0.05234	0.34457	120. 0 psia
0.94310	119.15000	0.05600	0.34650	
0.95529	122.62000	0.05963	0.34839	
0.96744	126.11000	0.06325	0.35025	
0.97954	129.63000	0.06686	0.35209	
0.99160	133.16000	0.07044	0.35389	
1.00360	136.70000	0.07401	0.35566	
1.01560	140.27000	0.07756	0.35739	
1.02750	143.85000	0.08109	0.35909	
1.03940	147.45000	0.08460	0.36075	
1.05130	151.07000	0.08810	0.36238	
1.06310	154.70000	0.09157	0.36396	
1.07490	158.34000	0.09503	0.36551	
0.01620	-133.56000	-0.26391	0.34898	130. 0 psia
0.01649	-121.38000	-0.24977	0.36041	
0.01680	-114.91000	-0.23571	0.37291	
0.01712	-105.64000	-0.22158	0.45774	
0.01749	-94.99300	-0.20774	0.40979	
0.01788	-84.50000	-0.19376	0.42875	
0.01830	-73.14200	-0.17977	0.44724	
0.69810	72.13100	0.00066	0.31953	
0.72923	80.08200	0.01045	0.32458	
0.75968	88.26060	0.02010	0.32968	
0.78956	96.56500	0.02963	0.33474	
0.81895	105.00000	0.03902	0.33973	
0.83058	108.40060	0.04275	0.34169	
0.84215	111.83000	0.04645	0.34362	
0.85366	115.28000	0.05014	0.34553	
0.86512	118.74000	0.05381	0.34742	
0.87652	122.22000	0.05746	0.34928	
0.88787	125.73000	0.06109	0.35111	
0.89917	129.25000	0.06470	0.35291	
0.91042	132.78000	0.06829	0.35469	
0.92163	136.34000	0.07187	0.35642	
0.93280	139.91000	0.07542	0.35813	
0.94393	143.50000	0.07896	0.35980	
0.95502	147.11000	0.08248	0.36144	
0.96607	150.73000	0.08598	0.36304	
0.97709	154.37000	0.08946	0.36460	
0.98807	158.02000	0.09293	0.36613	

Figure 8 . CP-34 Superheated Fluid Properties I (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.01620	-133.56000	-0.26391	0.34898	130. 0 psia
0.01649	-124.38000	-0.24977	0.36041	
0.01680	-114.91000	-0.23571	0.37291	
0.01712	-105.04000	-0.22188	0.45770	
0.01749	-94.99000	-0.20774	0.40979	
0.01788	-84.59000	-0.19376	0.42875	
0.01830	-73.64000	-0.17977	0.44724	
0.69810	72.05000	0.00066	0.31953	
0.72923	80.08000	0.01045	0.32458	
0.75968	88.26000	0.02010	0.32968	
0.78956	96.56000	0.02963	0.33474	
0.81895	105.00000	0.03902	0.33973	
0.83058	108.40000	0.04275	0.34169	
0.84215	111.83000	0.04645	0.34362	
0.85366	115.28000	0.05014	0.34553	
0.86512	118.74000	0.05381	0.34742	
0.87652	122.22000	0.05746	0.34928	
0.88787	125.73000	0.06109	0.35111	
0.89917	129.25000	0.06470	0.35291	
0.91042	132.78000	0.06829	0.35469	
0.92163	136.34000	0.07187	0.35642	
0.93280	139.91000	0.07542	0.35813	
0.94393	143.50000	0.07896	0.35980	
0.95502	147.11000	0.08248	0.36144	
0.96607	150.73000	0.08598	0.36304	
0.97709	154.37000	0.08946	0.36460	
0.98807	158.02000	0.09293	0.36613	
0.01620	-133.55000	-0.26392	0.34266	140. 0 psia
0.01648	-124.24000	-0.24997	0.45345	
0.01679	-114.79000	-0.23592	0.45475	
0.01712	-105.02000	-0.22191	0.45721	
0.01748	-94.91000	-0.20771	0.46043	
0.01787	-84.45000	-0.19391	0.46478	
0.01830	-73.64000	-0.17978	0.44489	
0.01876	-62.39000	-0.16578	0.46256	
0.66994	79.52400	0.00823	0.32632	
0.69879	87.74300	0.01793	0.33117	
0.72702	96.08300	0.02750	0.33606	
0.75475	104.54000	0.03693	0.34088	
0.76571	107.96000	0.04066	0.34279	
0.77661	111.40000	0.04438	0.34467	
0.78745	114.86000	0.04808	0.34655	
0.79822	118.33000	0.05176	0.34839	
0.80895	121.82000	0.05542	0.35020	
0.81961	125.34000	0.05906	0.35200	
0.83023	128.86000	0.06268	0.35376	
0.84080	132.41000	0.06628	0.35550	

Figure 9 . CP-34 Superheated Fluid Properties II -- Specific Volume, Enthalpy, Entropy, and Specific Heat

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.85133	135.97000	0.06986	0.35721	140. 0 psia
0.86181	139.55000	0.07342	0.35889	
0.87225	143.15000	0.07697	0.36053	
0.88265	146.77000	0.08049	0.36214	
0.89302	150.39000	0.08400	0.36372	
0.90335	154.04000	0.08749	0.36526	
0.91364	157.70000	0.09096	0.36676	
0.01619	-133.38000	-0.26414	0.45428	150. 0 psia
0.01648	-124.22000	-0.24999	0.45506	
0.01679	-114.78000	-0.23594	0.45422	
0.01712	-105.01000	-0.22193	0.45631	
0.01747	-94.90500	-0.20794	0.45978	
0.01786	-84.44000	-0.19394	0.46429	
0.01830	-73.63300	-0.17979	0.44313	
0.01876	-62.39600	-0.16579	0.46145	
0.61841	78.95400	0.00612	0.32318	
0.64590	87.21000	0.01587	0.33275	
0.67274	95.59300	0.02548	0.33742	
0.69904	104.03000	0.03495	0.34208	
0.70943	107.52000	0.03870	0.34393	
0.71975	110.97000	0.04243	0.34577	
0.73000	114.43000	0.04613	0.34759	
0.74020	117.92000	0.04982	0.34939	
0.75033	121.42000	0.05349	0.35116	
0.76042	124.94000	0.05714	0.35290	
0.77045	128.48000	0.06077	0.35464	
0.78043	132.03000	0.06438	0.35634	
0.79036	135.60000	0.06797	0.35802	
0.80025	139.19000	0.07154	0.35966	
0.81010	142.80000	0.07510	0.36128	
0.81991	146.42000	0.07863	0.36286	
0.82968	150.06000	0.08214	0.36441	
0.83941	153.71000	0.08564	0.36595	
0.84911	157.37000	0.08912	0.36741	
0.01619	-133.36000	-0.26416	0.45326	160. 0 psia
0.01647	-124.21000	-0.25002	0.45379	
0.01678	-114.76000	-0.23596	0.45404	
0.01712	-105.00000	-0.22196	0.45628	
0.01747	-94.89200	-0.20796	0.46049	
0.01786	-84.43500	-0.19397	0.46522	
0.01828	-73.60200	-0.17994	0.46585	
0.01876	-62.39500	-0.16580	0.45962	
0.57319	78.37200	0.00410	0.33014	
0.59951	86.67800	0.01391	0.33444	
0.62515	95.09400	0.02356	0.33887	
0.65022	103.62000	0.03306	0.34334	
0.66011	107.06000	0.03643	0.34512	
0.66993	110.52000	0.04017	0.34690	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.67969	114.00000	0.04429	0.34867	160. 0 psia
0.68937	117.50000	0.04749	0.35042	
0.69900	121.01000	0.05167	0.35214	
0.70858	124.54000	0.05533	0.35385	
0.71810	128.09000	0.05897	0.35554	
0.72756	131.65000	0.06259	0.35721	
0.73698	135.23000	0.06619	0.35885	
0.74636	138.83000	0.06977	0.36046	
0.75569	142.44000	0.07333	0.36205	
0.76498	146.07000	0.07687	0.36360	
0.77423	149.71000	0.08039	0.36512	
0.78344	153.37000	0.08389	0.36661	
0.79262	157.04000	0.08737	0.36807	
0.01618	-133.34000	-0.26418	0.45394	170. 0 psia
0.01647	-124.19000	-0.25004	0.45383	
0.01678	-114.75000	-0.23599	0.45416	
0.01711	-104.98000	-0.22199	0.45625	
0.01747	-94.88200	-0.20799	0.45962	
0.01786	-84.42000	-0.19400	0.46491	
0.01828	-73.59400	-0.17997	0.46888	
0.01876	-62.39000	-0.16581	0.45798	
0.01927	-50.75700	-0.15177	0.47760	
0.55847	86.13000	0.01202	0.33620	
0.58308	94.58700	0.02172	0.34039	
0.60708	103.15000	0.03127	0.34466	
0.61654	105.61000	0.03504	0.34637	
0.62592	110.08000	0.03880	0.34809	
0.63524	113.57000	0.04253	0.34979	
0.64448	117.07000	0.04624	0.35149	
0.65367	120.60000	0.04993	0.35316	
0.66279	124.14000	0.05360	0.35482	
0.67186	127.69000	0.05725	0.35647	
0.68088	131.27000	0.06088	0.35810	
0.68985	134.86000	0.06449	0.35970	
0.69877	138.46000	0.06808	0.36129	
0.70765	142.08000	0.07165	0.36283	
0.71649	145.72000	0.07519	0.36436	
0.72528	149.37000	0.07872	0.36586	
0.73404	153.03000	0.08223	0.36732	
0.74276	156.71000	0.08572	0.36875	
0.01618	-133.33000	-0.26420	0.45382	180. 0 psia
0.01647	-124.18000	-0.25006	0.45358	
0.01678	-114.73000	-0.23601	0.45524	
0.01711	-104.97000	-0.22201	0.45789	
0.01747	-94.86000	-0.20802	0.45978	
0.01785	-84.41000	-0.19403	0.46497	
0.01828	-73.58500	-0.18001	0.46866	
0.01874	-62.37000	-0.16594	0.47337	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.01927	-50.75700	-0.15178	0.47416	180.0 psia
0.52189	85.57100	0.01021	0.33809	
0.54559	94.07100	0.01996	0.34198	
0.56867	102.67000	0.02954	0.34603	
0.57775	106.14000	0.03334	0.34767	
0.58674	109.62000	0.03711	0.34932	
0.59567	113.13000	0.04085	0.35096	
0.60453	116.64000	0.04458	0.35260	
0.61332	120.18000	0.04828	0.35422	
0.62206	123.73000	0.05196	0.35584	
0.63073	127.29000	0.05562	0.35744	
0.63935	130.88000	0.05925	0.35902	
0.64792	134.48000	0.06287	0.36059	
0.65645	138.09000	0.06647	0.36213	
0.66492	141.72000	0.07004	0.36364	
0.67335	145.36000	0.07360	0.36513	
0.68175	149.02000	0.07714	0.36660	
0.69010	152.69000	0.08065	0.36804	
0.69841	156.38000	0.08415	0.36944	
0.01618	-133.31000	-0.26422	0.45286	190.0 psia
0.01647	-124.16000	-0.25008	0.45234	
0.01678	-114.72000	-0.23603	0.45512	
0.01711	-103.96000	-0.22204	0.45677	
0.01747	-94.85600	-0.20805	0.46018	
0.01785	-84.40200	-0.19406	0.46429	
0.01827	-73.57700	-0.18004	0.46848	
0.01874	-62.36800	-0.16598	0.47321	
0.01927	-50.75700	-0.15179	0.47447	
0.48904	84.99000	0.00846	0.34011	
0.51197	93.54500	0.01826	0.34367	
0.53423	102.18000	0.02759	0.34747	
0.54297	105.67000	0.03159	0.34903	
0.55164	109.17000	0.03548	0.35060	
0.56022	112.68000	0.03924	0.35218	
0.56874	116.21000	0.04297	0.35376	
0.57718	119.75000	0.04669	0.35532	
0.58557	123.32000	0.05038	0.35688	
0.59389	126.89000	0.05405	0.35843	
0.60216	130.48000	0.05770	0.35997	
0.61038	134.09000	0.06132	0.36150	
0.61854	137.71000	0.06493	0.36300	
0.62666	141.35000	0.06851	0.36448	
0.63474	145.00000	0.07208	0.36594	
0.64277	148.67000	0.07562	0.36737	
0.65076	152.35000	0.07914	0.36878	
0.65872	155.04000	0.08265	0.37015	
0.01618	-133.29000	-0.26424	0.45391	200.0 psia
0.01647	-124.14000	-0.25011	0.45494	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.01678	-111.70000	-0.23606	0.45527	200.0 psia
0.01711	-104.94000	-0.22206	0.45563	
0.01746	-94.84300	-0.20808	0.46145	
0.01785	-84.39100	-0.19409	0.46370	
0.01827	-73.56900	-0.18007	0.46845	
0.01873	-62.36300	-0.16602	0.47312	
0.01926	-50.75600	-0.15181	0.47354	
0.45937	84.41400	0.00676	0.34227	
0.48162	93.00900	0.01661	0.34545	
0.50317	101.69000	0.02629	0.34899	
0.51162	105.19000	0.03011	0.35045	
0.51998	108.70000	0.03391	0.35195	
0.52826	112.23000	0.03768	0.35344	
0.53647	115.77000	0.04143	0.35495	
0.54461	119.32000	0.04516	0.35646	
0.55269	122.90000	0.04886	0.35797	
0.56070	126.48000	0.05254	0.35946	
0.56866	130.09000	0.05620	0.36095	
0.57656	133.70000	0.05984	0.36243	
0.58440	137.33000	0.06345	0.36389	
0.59221	140.98000	0.06705	0.36533	
0.59996	144.64000	0.07062	0.36675	
0.60767	148.32000	0.07417	0.36816	
0.61534	152.00000	0.07770	0.36953	
0.62297	155.71000	0.08121	0.37088	
0.01618	-133.28000	-0.26426	0.45323	210.0 psia
0.01647	-124.13000	-0.25013	0.45370	
0.01678	-111.69000	-0.23608	0.45407	
0.01711	-104.93000	-0.22209	0.45708	
0.01746	-94.83100	-0.20811	0.45990	
0.01786	-84.43100	-0.19397	0.42488	
0.01827	-73.56100	-0.18010	0.46891	
0.01873	-62.35400	-0.16605	0.47293	
0.01925	-50.75100	-0.15194	0.47775	
0.43241	83.81500	0.00510	0.34459	
0.45408	92.46300	0.01502	0.34736	
0.47500	101.19000	0.02474	0.35058	
0.48319	104.70000	0.02858	0.35196	
0.49129	108.23000	0.03240	0.35336	
0.49930	111.77000	0.03618	0.35477	
0.50724	115.32000	0.03995	0.35621	
0.51511	118.89000	0.04368	0.35764	
0.52290	122.47000	0.04740	0.35908	
0.53064	126.07000	0.05109	0.36053	
0.53831	129.68000	0.05476	0.36197	
0.54592	133.31000	0.05841	0.36340	
0.55349	136.95000	0.06203	0.36482	
0.56100	140.61000	0.06563	0.36621	
0.56847	144.28000	0.06921	0.36760	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.57589	147.96000	0.07277	0.36897	210. 0 psia
0.58327	151.66000	0.07631	0.37030	
0.59061	155.37000	0.07983	0.37163	
0.01618	-133.26000	-0.26428	0.45298	220. 0 psia
0.01647	-124.11000	-0.25015	0.45336	
0.01677	-114.67000	-0.23610	0.45509	
0.01711	-104.91000	-0.22211	0.45715	
0.01746	-94.81900	-0.20813	0.46021	
0.01784	-84.37100	-0.19415	0.46457	
0.01826	-73.55200	-0.18014	0.46866	
0.01873	-62.35200	-0.16609	0.47293	
0.01924	-50.74900	-0.15198	0.47763	
0.01983	-38.71500	-0.13775	0.48686	
0.42896	91.90400	0.01346	0.34938	
0.44932	100.67000	0.02324	0.35227	
0.45728	104.20000	0.02710	0.35352	
0.46515	107.74000	0.03093	0.35482	
0.47292	111.30000	0.03473	0.35516	
0.48062	114.87000	0.03851	0.35752	
0.48824	118.45000	0.04226	0.35887	
0.49579	122.05000	0.04599	0.36025	
0.50327	125.65000	0.04969	0.36162	
0.51069	129.28000	0.05337	0.36301	
0.51805	132.92000	0.05702	0.36439	
0.52536	136.57000	0.06066	0.36577	
0.53261	140.23000	0.06427	0.36713	
0.53982	143.91000	0.06786	0.36847	
0.54698	147.60000	0.07143	0.36980	
0.55409	151.30000	0.07497	0.37111	
0.56117	155.02000	0.07850	0.37239	
0.01618	-133.24000	-0.26430	0.45410	230. 0 psia
0.01647	-124.10000	-0.25017	0.45401	
0.01677	-114.65000	-0.23613	0.45552	
0.01710	-104.90000	-0.22214	0.45674	
0.01746	-94.80800	-0.20816	0.46003	
0.01784	-84.35900	-0.19418	0.46481	
0.01826	-73.54400	-0.18017	0.46879	
0.01872	-62.34700	-0.16613	0.47327	
0.01924	-50.74700	-0.15202	0.47794	
0.01983	-38.71600	-0.13776	0.48791	
0.40593	91.33400	0.01195	0.35154	
0.42581	100.15000	0.02177	0.35406	
0.43357	103.70000	0.02565	0.35518	
0.44122	107.26000	0.02956	0.35637	
0.44879	110.83000	0.03342	0.35761	
0.45626	114.41000	0.03711	0.35887	
0.46366	118.00000	0.04088	0.36015	
0.47099	121.61000	0.04462	0.36146	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.47824	125.23000	0.04833	0.36277	230. 0 psia
0.48544	128.87000	0.05202	0.36411	
0.49257	132.52100	0.05569	0.36543	
0.49964	136.18000	0.05933	0.36676	
0.50666	139.85000	0.06295	0.36806	
0.51364	143.54000	0.06655	0.36935	
0.52056	147.24000	0.07013	0.37065	
0.52744	150.95000	0.07368	0.37192	
0.53427	154.68000	0.07722	0.37317	
0.01617	-133.22000	-0.26433	0.45209	240. 0 psia
0.01646	-124.03000	-0.25019	0.45463	
0.01677	-114.64000	-0.23616	0.45450	
0.01710	-104.89000	-0.22216	0.45662	
0.01746	-94.79400	-0.20819	0.45962	
0.01784	-84.35000	-0.19421	0.46494	
0.01826	-73.53600	-0.18020	0.46882	
0.01872	-62.34100	-0.16616	0.47318	
0.01923	-50.74600	-0.15206	0.47719	
0.01983	-38.71700	-0.13778	0.48844	
0.38472	90.75000	0.01046	0.35389	
0.40419	99.62100	0.02035	0.35592	
0.41177	103.13000	0.02424	0.35693	
0.41924	106.75000	0.02811	0.35806	
0.42661	110.35000	0.03194	0.35913	
0.43390	113.94000	0.03575	0.36030	
0.44110	117.55000	0.03953	0.36149	
0.44822	121.17000	0.04329	0.36273	
0.45527	124.81000	0.04701	0.36397	
0.46226	128.45000	0.05072	0.36523	
0.46918	132.11000	0.05439	0.36651	
0.47605	135.78000	0.05805	0.36776	
0.48285	139.47000	0.06168	0.36902	
0.48961	143.16000	0.06529	0.37027	
0.49632	146.87000	0.06887	0.37152	
0.50298	150.59000	0.07243	0.37276	
0.50960	154.33000	0.07597	0.37397	
0.01617	-133.21000	-0.26434	0.45376	250. 0 psia
0.01646	-124.06000	-0.25022	0.45352	
0.01677	-114.63900	-0.23618	0.45397	
0.01710	-104.87000	-0.22219	0.45671	
0.01745	-94.78200	-0.20821	0.46043	
0.01784	-84.33000	-0.19424	0.46438	
0.01825	-73.52300	-0.18023	0.46860	
0.01872	-62.33500	-0.16620	0.47272	
0.01923	-50.74100	-0.15210	0.47812	
0.01981	-38.72500	-0.13791	0.48556	
0.35512	90.15200	0.00900	0.35633	
0.38423	99.07600	0.01895	0.35793	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

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VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.39165	102.65000	0.02287	0.35878	250. 0 psia
0.39896	106.25000	0.02675	0.35971	
0.40616	109.86000	0.03060	0.36072	
0.41327	113.47000	0.03443	0.36179	
0.42029	117.09000	0.03822	0.36289	
0.42724	120.73000	0.04199	0.36404	
0.43410	124.37000	0.04573	0.36520	
0.44090	128.03000	0.04945	0.36639	
0.44764	131.70000	0.05314	0.36759	
0.45431	135.38000	0.05680	0.36881	
0.46093	139.08000	0.06044	0.37002	
0.46749	142.78000	0.06406	0.37123	
0.47400	146.50000	0.06765	0.37243	
0.48046	150.23000	0.07122	0.37362	
0.48688	153.97000	0.07477	0.37479	
0.01617	-133.19000	-0.26437	0.45384	260. 0 psia
0.01646	-124.05000	-0.25024	0.45438	
0.01677	-114.61000	-0.23620	0.45487	
0.01710	-104.86000	-0.22221	0.45631	
0.01745	-94.76900	-0.20824	0.45962	
0.01783	-84.32900	-0.19427	0.46404	
0.01825	-73.51900	-0.18027	0.46829	
0.01871	-62.33000	-0.16623	0.47293	
0.01922	-50.74200	-0.15214	0.47791	
0.01980	-38.72200	-0.13706	0.48042	
0.34693	94.53900	0.00756	0.35902	
0.36573	98.52500	0.01758	0.36005	
0.37301	102.13000	0.02152	0.36072	
0.38018	105.74000	0.02542	0.36152	
0.38723	109.36000	0.02929	0.36240	
0.39418	112.99000	0.03314	0.36335	
0.40105	116.63000	0.03695	0.36434	
0.40783	120.27000	0.04073	0.36540	
0.41453	123.93000	0.04448	0.36648	
0.42116	127.61000	0.04821	0.36761	
0.42772	131.29000	0.05191	0.36875	
0.43422	134.98000	0.05559	0.36988	
0.44066	138.68000	0.05924	0.37105	
0.44704	142.40000	0.06287	0.37220	
0.45338	146.13000	0.06647	0.37335	
0.45966	149.87000	0.07005	0.37450	
0.46590	153.62000	0.07360	0.37564	
0.01617	-133.17000	-0.26439	0.45277	270. 0 psia
0.01646	-124.03000	-0.25026	0.45333	
0.01678	-114.73000	-0.23601	0.36319	
0.01710	-104.85000	-0.22224	0.45538	
0.01745	-94.75700	-0.20827	0.46092	
0.01783	-84.31800	-0.19430	0.46425	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.01825	-73.51000	-0.18030	0.46900	270. 0 psia
0.01871	-62.32400	-0.16627	0.47284	
0.01922	-50.74000	-0.15218	0.47747	
0.01980	-38.73300	-0.13801	0.48565	
0.02048	-26.25200	-0.12368	0.50902	
0.34853	97.95900	0.01623	0.36233	
0.35569	101.58000	0.02019	0.36280	
0.36273	105.22000	0.02412	0.36343	
0.36965	108.85000	0.02801	0.36417	
0.37647	112.50000	0.03187	0.36499	
0.38319	116.15000	0.03570	0.36588	
0.38982	119.82000	0.03950	0.36682	
0.39637	123.49000	0.04326	0.36783	
0.40285	127.17000	0.04701	0.36887	
0.40925	130.87000	0.05072	0.36994	
0.41559	134.57000	0.05441	0.37102	
0.42187	138.29000	0.05807	0.37210	
0.42809	142.01000	0.06170	0.37320	
0.43426	145.75000	0.06532	0.37432	
0.44038	149.50000	0.06890	0.37542	
0.44645	153.25000	0.07247	0.37651	
0.01617	-133.16000	-0.26441	0.45370	280. 0 psia
0.01646	-124.02000	-0.25028	0.45570	
0.01677	-114.58000	-0.23625	0.45574	
0.01709	-104.83000	-0.22226	0.45606	
0.01745	-94.71000	-0.20830	0.46117	
0.01783	-84.31700	-0.19433	0.46451	
0.01824	-73.51200	-0.18033	0.46894	
0.01870	-62.31000	-0.16630	0.47278	
0.01921	-50.73500	-0.15222	0.47778	
0.01979	-38.73000	-0.13805	0.48611	
0.02047	-26.25400	-0.12370	0.50230	
0.33249	97.33000	0.01490	0.36473	
0.33965	101.03000	0.01889	0.36500	
0.34647	104.68000	0.02284	0.36545	
0.35327	108.34000	0.02675	0.36603	
0.35997	112.00000	0.03063	0.36671	
0.36656	115.67000	0.03447	0.36748	
0.37306	119.35000	0.03829	0.36832	
0.37947	123.04000	0.04207	0.36923	
0.38581	126.74000	0.04583	0.37018	
0.39207	130.44000	0.04955	0.37116	
0.39827	134.16000	0.05325	0.37218	
0.40440	137.89000	0.05693	0.37321	
0.41047	141.62000	0.06057	0.37423	
0.41649	145.37000	0.06419	0.37530	
0.42246	149.13000	0.06779	0.37635	
0.42837	152.90000	0.07136	0.37740	
0.01617	-133.14000	-0.26443	0.45308	290. 0 psia

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Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb°F)	CTAB (Btu/lb°F)	
0.01646	-124.00000	-0.25030	0.45370	290. 0 psia
0.01677	-114.56000	-0.23627	0.45503	
0.01709	-104.82000	-0.22229	0.45662	
0.01744	-94.73300	-0.20832	0.45904	
0.01783	-84.29600	-0.19436	0.46420	
0.01824	-73.49400	-0.18036	0.46879	
0.01870	-62.31200	-0.16634	0.47309	
0.01921	-50.73600	-0.15226	0.47763	
0.01979	-38.73800	-0.13810	0.48553	
0.02046	-26.27500	-0.12381	0.50830	
0.31747	96.78800	0.01359	0.36735	
0.32444	100.46000	0.01760	0.36738	
0.33127	104.14000	0.02158	0.36761	
0.33797	107.81000	0.02551	0.36801	
0.34456	111.50000	0.02941	0.36853	
0.35104	115.19000	0.03327	0.36917	
0.35742	118.88000	0.03710	0.36988	
0.36371	122.58000	0.04090	0.37067	
0.36992	126.29000	0.04467	0.37155	
0.37605	130.01000	0.04841	0.37245	
0.38211	133.74000	0.05212	0.37339	
0.38811	137.48000	0.05581	0.37433	
0.39405	141.23000	0.05947	0.37531	
0.39992	144.99000	0.06310	0.37632	
0.40575	148.76000	0.06670	0.37731	
0.41152	152.53000	0.07029	0.37830	
0.01617	-133.13000	-0.26445	0.45431	300. 0 psia
0.01646	-123.98000	-0.25043	0.45398	
0.01676	-114.55000	-0.23630	0.45382	
0.01709	-104.89000	-0.22232	0.45585	
0.01744	-94.72100	-0.20835	0.45969	
0.01782	-84.28500	-0.19439	0.46494	
0.01824	-73.48400	-0.18040	0.46863	
0.01870	-62.30700	-0.16638	0.47309	
0.01920	-50.73300	-0.15230	0.47766	
0.01978	-38.74100	-0.13814	0.48577	
0.02045	-26.28500	-0.12346	0.50806	
0.30337	96.18100	0.01229	0.37014	
0.31027	99.88100	0.01633	0.36990	
0.31703	103.58000	0.02033	0.36990	
0.32364	107.28000	0.02429	0.37009	
0.33013	110.98000	0.02821	0.37044	
0.33650	114.69000	0.03209	0.37093	
0.34278	118.40000	0.03594	0.37153	
0.34896	122.12000	0.03976	0.37220	
0.35505	125.85000	0.04354	0.37296	
0.36107	129.58000	0.04729	0.37377	
0.36701	133.32000	0.05102	0.37463	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.37288	137.07000	0.05472	0.37551	
0.37869	140.83000	0.05859	0.37642	300. 0 psia
0.38444	144.60000	0.06203	0.37736	
0.39014	148.38000	0.06564	0.37831	
0.39578	152.17000	0.06923	0.37925	
0.01617	-133.09000	-0.26449	0.45345	
0.01645	-123.95000	-0.25037	0.45395	
0.01676	-114.52000	-0.23634	0.45561	
0.01709	-104.78000	-0.22236	0.45687	
0.01744	-94.69400	-0.20841	0.45888	
0.01782	-84.26300	-0.19445	0.46395	
0.01823	-73.46800	-0.18046	0.46826	
0.01869	-62.29500	-0.16645	0.47312	
0.01919	-50.72900	-0.15238	0.47778	
0.01977	-38.74600	-0.13823	0.48531	
0.02043	-26.30400	-0.12397	0.50753	
0.27756	94.91700	0.00972	0.37650	
0.28438	98.67700	0.01383	0.37555	320. 0 psia
0.29101	102.43000	0.01789	0.37497	
0.29749	106.18000	0.02190	0.37468	
0.30382	109.92000	0.02586	0.37463	
0.31003	113.67000	0.02979	0.37475	
0.31613	117.42000	0.03367	0.37505	
0.32212	121.17000	0.03752	0.37546	
0.32802	124.93000	0.04134	0.37598	
0.33383	128.69000	0.04512	0.37660	
0.33956	132.46000	0.04887	0.37728	
0.34521	136.24000	0.05259	0.37800	
0.35080	140.02000	0.05629	0.37874	
0.35633	143.81000	0.05995	0.37956	
0.36180	147.61000	0.06359	0.38039	
0.36721	151.42000	0.06720	0.38121	
0.01616	-133.05000	-0.26453	0.45305	
0.01645	-123.92000	-0.25042	0.45361	
0.01676	-114.49000	-0.23639	0.45428	
0.01708	-104.75000	-0.22242	0.45575	
0.01743	-94.67000	-0.20846	0.45990	
0.01781	-84.24200	-0.19450	0.46441	
0.01823	-73.45000	-0.18053	0.46842	
0.01868	-62.28300	-0.16652	0.47309	340. 0 psia
0.01919	-50.72400	-0.15246	0.47787	
0.01976	-38.75100	-0.13833	0.48488	
0.02041	-26.32300	-0.12408	0.50713	
0.02120	-13.36900	-0.10964	0.53051	
0.26121	97.40700	0.01135	0.38216	
0.26779	101.22000	0.01548	0.38083	
0.27418	105.02000	0.01955	0.37992	
0.28041	108.82000	0.02356	0.37936	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.28650	112.61000	0.02753	0.37905	340. 0 psia
0.29245	116.40000	0.03146	0.37897	
0.29830	120.19000	0.03535	0.37906	
0.30403	123.99000	0.03920	0.37931	
0.30968	127.78000	0.04302	0.37967	
0.31523	131.58000	0.04680	0.38013	
0.32071	135.38000	0.05055	0.38066	
0.32611	139.19000	0.05427	0.38126	
0.33145	143.01000	0.05795	0.38192	
0.33672	146.83000	0.06161	0.38260	
0.34193	150.66000	0.06524	0.38331	
0.01616	-133.02000	-0.26457	0.45388	360. 0 psia
0.01645	-123.89000	-0.25046	0.45212	
0.01675	-114.46000	-0.23644	0.45419	
0.01708	-104.72000	-0.22247	0.45575	
0.01743	-94.64500	-0.20851	0.46037	
0.01781	-84.22100	-0.19456	0.46463	
0.01822	-73.43500	-0.18059	0.46863	
0.01867	-62.27100	-0.16659	0.47275	
0.01918	-50.71900	-0.15254	0.47772	
0.01974	-38.75500	-0.13842	0.48463	
0.02040	-26.34000	-0.12418	0.50620	
0.02118	-13.49700	-0.10977	0.52958	
0.02155	-8.01490	-0.10367	0.54018	
0.24685	99.94300	0.01308	0.38770	
0.25321	103.82000	0.01722	0.38599	
0.25938	107.67000	0.02130	0.38476	
0.26538	111.51000	0.02533	0.38389	
0.27124	115.35000	0.02930	0.38334	
0.27697	119.18000	0.03323	0.38306	
0.28259	123.01000	0.03712	0.38297	
0.28809	126.84000	0.04097	0.38304	
0.29351	130.67000	0.04479	0.38325	
0.29883	134.51000	0.04856	0.38355	
0.30408	138.34000	0.05231	0.38394	
0.30925	142.19000	0.05602	0.38442	
0.31436	146.03000	0.05970	0.38495	
0.31940	149.88000	0.06336	0.38553	
0.01616	-132.99000	-0.26462	0.45348	380. 0 psia
0.01645	-123.85000	-0.25050	0.45345	
0.01675	-114.43000	-0.23648	0.45444	
0.01708	-104.69000	-0.22252	0.45588	
0.01743	-94.61800	-0.20857	0.46058	
0.01780	-84.19900	-0.19462	0.46382	
0.01821	-73.41500	-0.18066	0.46826	
0.01867	-62.25900	-0.16666	0.47293	
0.01917	-50.71400	-0.15262	0.47735	
0.01973	-38.75900	-0.13851	0.48466	

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Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.02038	-26.35700	-0.12429	0.50564	380. 0 psia
0.02116	-13.44500	-0.10989	0.52841	
0.02151	-8.10970	-0.10406	0.53943	
0.02191	-2.65370	-0.09816	0.55193	
0.23417	102.54000	0.01490	0.39312	
0.24033	106.46000	0.01985	0.39098	
0.24629	110.36000	0.02314	0.38941	
0.25209	114.25000	0.02717	0.38830	
0.25774	118.13000	0.03115	0.38752	
0.26326	122.00000	0.03508	0.38701	
0.26866	125.87000	0.03897	0.38673	
0.27396	129.74000	0.04282	0.38664	
0.27916	133.60000	0.04663	0.38669	
0.28428	137.47000	0.05041	0.38686	
0.28931	141.34000	0.05415	0.38714	
0.29428	145.22000	0.05785	0.38747	
0.29917	149.09000	0.06153	0.38789	
0.01616	-132.95000	-0.26466	0.45212	400. 0 psia
0.01644	-123.82000	-0.25055	0.45379	
0.01675	-111.40000	-0.23653	0.45348	
0.01707	-104.66000	-0.22257	0.45696	
0.01742	-94.59400	-0.20862	0.45870	
0.01780	-84.17600	-0.19468	0.46435	
0.01821	-73.39700	-0.18072	0.46888	
0.01866	-62.24500	-0.16674	0.47284	
0.01916	-50.70500	-0.15270	0.47769	
0.01972	-38.76300	-0.13860	0.48194	
0.02037	-26.37500	-0.12439	0.50444	
0.02113	-13.48100	-0.11002	0.52733	
0.02149	-8.25740	-0.10420	0.53810	
0.02188	-2.71681	-0.09832	0.55125	
0.21672	101.29000	0.01258	0.40156	
0.22292	105.19000	0.01681	0.39833	
0.22889	109.16000	0.02097	0.39580	
0.23466	113.11000	0.02506	0.39394	
0.24027	117.04000	0.02910	0.39253	
0.24572	120.96000	0.03308	0.39153	
0.25105	124.87000	0.03701	0.39084	
0.25626	128.78000	0.04090	0.39038	
0.26136	132.68000	0.04474	0.39012	
0.26637	136.58000	0.04855	0.39000	
0.27129	140.48000	0.05232	0.39005	
0.27614	144.38000	0.05605	0.39020	
0.28091	148.28000	0.05975	0.39042	
0.01615	-132.92100	-0.26470	0.45370	420. 0 psia
0.01644	-123.79000	-0.25059	0.45383	
0.01674	-114.37000	-0.23658	0.45391	
0.01707	-103.64500	-0.22262	0.45770	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.01742	-94.57000	-0.20868	0.46027	420. 0 psia
0.01779	-84.15400	-0.19474	0.46361	
0.01820	-73.37900	-0.18079	0.46845	
0.01865	-62.23300	-0.16680	0.47306	
0.01915	-50.70200	-0.15278	0.47744	
0.01971	-38.76600	-0.13869	0.48432	
0.02035	-26.39000	-0.12450	0.50419	
0.02111	-13.51600	-0.11015	0.52633	
0.02146	-8.20400	-0.10434	0.53748	
0.02185	-2.77820	-0.09847	0.54920	
0.02228	2.77290	-0.09253	0.56249	
0.20687	103.83000	0.01455	0.40714	
0.21290	107.89000	0.01879	0.40331	
0.21869	111.90000	0.02296	0.40045	
0.22428	115.90000	0.02705	0.39827	
0.22970	119.87000	0.03109	0.39662	
0.23498	123.83000	0.03507	0.39540	
0.24013	127.78000	0.03900	0.39450	
0.24515	131.72000	0.04289	0.39387	
0.25008	135.66000	0.04673	0.39345	
0.25491	139.59000	0.05053	0.39323	
0.25965	143.52000	0.05429	0.39312	
0.26432	147.46000	0.05802	0.39313	
0.01615	-132.89000	-0.26474	0.45271	440. 0 psia
0.01644	-123.76000	-0.25063	0.45355	
0.01674	-114.34000	-0.23662	0.45373	
0.01707	-104.61000	-0.22267	0.45557	
0.01741	-94.54300	-0.20873	0.45962	
0.01779	-84.13200	-0.19480	0.46389	
0.01820	-73.36100	-0.18085	0.46817	
0.01864	-62.22000	-0.16688	0.47300	
0.01914	-50.69600	-0.15286	0.47794	
0.01970	-38.76900	-0.13878	0.48262	
0.02033	-26.40000	-0.12460	0.50344	
0.02109	-13.55100	-0.11027	0.52565	
0.02144	-8.24870	-0.10447	0.53597	
0.02182	-2.83670	-0.09862	0.54809	
0.02224	2.69770	-0.09270	0.56054	
0.02272	8.38930	-0.08667	0.57836	
0.19808	106.54000	0.01659	0.41231	
0.20393	110.64000	0.02084	0.40808	
0.20955	114.70000	0.02502	0.40487	
0.21498	118.74000	0.02911	0.40241	
0.22023	122.75000	0.03315	0.40055	
0.22534	126.75000	0.03713	0.39910	
0.23031	130.74000	0.04106	0.39801	
0.23517	134.71000	0.04494	0.39722	
0.23993	138.68000	0.04877	0.39667	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.24459	142.65000	0.05257	0.39629	440. 0 psia
0.24917	146.61000	0.05632	0.39606	
0.01615	-132.85000	-0.26478	0.45370	460. 0 psia
0.01644	-123.73000	-0.25068	0.45361	
0.01674	-114.31000	-0.23667	0.45407	
0.01706	-104.58000	-0.22272	0.45594	
0.01741	-94.51700	-0.20878	0.46021	
0.01778	-84.11000	-0.19486	0.46407	
0.01819	-73.34300	-0.18092	0.46804	
0.01864	-62.20800	-0.16695	0.47290	
0.01913	-51.69000	-0.15294	0.47772	
0.01968	-38.77100	-0.13887	0.48203	
0.02032	-26.42100	-0.12471	0.50320	
0.02107	-13.58600	-0.11040	0.52442	
0.02141	-8.29230	-0.10461	0.53550	
0.02179	-2.89330	-0.09877	0.54611	
0.02220	2.62550	-0.09286	0.55859	
0.02267	8.29120	-0.08686	0.57458	
0.18424	105.09000	0.01435	0.42330	
0.19021	109.30000	0.01871	0.41721	
0.19590	113.44000	0.02297	0.41261	
0.20135	117.55000	0.02714	0.40907	
0.20662	121.63000	0.03124	0.40635	
0.21171	125.68000	0.03527	0.40425	
0.21665	129.72000	0.03925	0.40262	
0.22147	133.74000	0.04317	0.40136	
0.22617	137.74000	0.04704	0.40042	
0.23077	141.74000	0.05087	0.39973	
0.23527	145.74000	0.05466	0.39921	
0.01615	-132.82000	-0.26482	0.45274	480. 0 psia
0.01643	-123.69000	-0.25072	0.45404	
0.01674	-114.28000	-0.23672	0.45422	
0.01706	-104.55000	-0.22277	0.45585	
0.01740	-94.49100	-0.20884	0.46021	
0.01778	-84.08300	-0.19492	0.46389	
0.01818	-73.32400	-0.18098	0.46838	
0.01863	-62.19300	-0.16702	0.47290	
0.01912	-51.68300	-0.15302	0.47772	
0.01967	-38.77400	-0.13896	0.48172	
0.02030	-26.43600	-0.12481	0.50252	
0.02105	-13.61300	-0.11052	0.52361	
0.02139	-8.33300	-0.10474	0.53340	
0.02176	-2.94930	-0.09892	0.54512	
0.02217	2.55390	-0.09303	0.55689	
0.02263	8.19780	-0.08705	0.57263	
0.02316	14.01100	-0.08096	0.59288	
0.17733	107.86000	0.01653	0.42837	
0.18314	112.11000	0.02089	0.42180	
0.18867	116.30000	0.02515	0.41684	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.19397	120.45000	0.02952	0.41306	480.0 psia
0.19907	124.57000	0.03341	0.41008	
0.20401	128.66000	0.03744	0.40776	
0.20880	132.73000	0.04141	0.40596	
0.21346	136.78000	0.04533	0.40455	
0.21801	140.82000	0.04920	0.40347	
0.22246	144.85000	0.05302	0.40264	
0.01615	-132.79000	-0.26486	0.45212	500.0 psia
0.01643	-123.66000	-0.25077	0.45194	
0.01673	-114.25000	-0.23676	0.45354	
0.01705	-104.52000	-0.22282	0.45619	
0.01740	-94.46500	-0.20889	0.45879	
0.01777	-84.06400	-0.19498	0.46364	
0.01818	-73.30600	-0.18104	0.46863	
0.01862	-62.18000	-0.16709	0.47262	
0.01911	-50.67600	-0.15309	0.47784	
0.01966	-38.77600	-0.13905	0.48212	
0.02029	-26.45000	-0.12491	0.50218	
0.02102	-13.65000	-0.11065	0.52287	
0.02136	-8.37800	-0.10488	0.53247	
0.02173	-3.00370	-0.09907	0.54357	
0.02213	2.48460	-0.09319	0.55453	
0.02259	8.10690	-0.08723	0.56975	
0.02311	13.89500	-0.08117	0.58842	
0.16514	106.31000	0.01428	0.44243	
0.17113	110.69000	0.01877	0.43303	
0.17678	114.98000	0.02313	0.42608	
0.18215	119.22000	0.02738	0.42082	
0.18730	123.40000	0.03155	0.41674	
0.19225	127.56000	0.03564	0.41358	
0.19704	131.68000	0.03967	0.41107	
0.20168	135.78000	0.04363	0.40911	
0.20620	139.86000	0.04754	0.40757	
0.21061	143.93000	0.05140	0.40634	
0.01614	-132.75000	-0.26490	0.45230	520.0 psia
0.01643	-123.63000	-0.25081	0.45305	
0.01673	-114.22000	-0.23681	0.45376	
0.01705	-104.49000	-0.22287	0.45541	
0.01740	-94.44000	-0.20895	0.45904	
0.01777	-84.04200	-0.19504	0.46432	
0.01817	-73.28700	-0.18111	0.46811	
0.01861	-62.16700	-0.16716	0.47281	
0.01910	-50.66900	-0.15317	0.47738	
0.01965	-38.77700	-0.13914	0.48209	
0.02027	-26.46400	-0.12502	0.49459	
0.02100	-13.68100	-0.11077	0.52154	
0.02133	-8.41840	-0.10501	0.53160	
0.02170	-3.05500	-0.09921	0.54249	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)	
0.02210	2.41660	-0.09336	0.55262	520. 0 psia
0.02255	6.02270	-0.08742	0.56771	
0.02305	13.78200	-0.08138	0.58709	
0.02365	19.74700	-0.07520	0.60912	
0.15972	109.16000	0.01658	0.44708	
0.16556	113.58000	0.02107	0.43729	
0.17105	117.91000	0.02543	0.43002	
0.17627	122.18000	0.02968	0.42449	
0.18126	126.41000	0.03384	0.42022	
0.18606	130.59000	0.03792	0.41684	
0.19071	134.74000	0.04194	0.41421	
0.19521	138.88000	0.04589	0.41208	
0.19959	142.99000	0.04979	0.41040	
0.01614	-132.72000	-0.26495	0.45286	540. 0 psia
0.01642	-123.59000	-0.25085	0.45352	
0.01673	-114.19000	-0.23636	0.45404	
0.01705	-104.47000	-0.22202	0.45439	
0.01739	-94.41700	-0.20900	0.45978	
0.01776	-84.01900	-0.19509	0.46364	
0.01817	-73.26600	-0.18117	0.46835	
0.01861	-62.15300	-0.16723	0.47272	
0.01909	-50.66100	-0.15325	0.47784	
0.01964	-38.77600	-0.13923	0.48221	
0.02026	-26.47700	-0.12512	0.49515	
0.02098	-13.71200	-0.11089	0.52082	
0.02131	-7.45830	-0.10514	0.53114	
0.02167	-3.10690	-0.09936	0.54109	
0.02206	2.35160	-0.09351	0.55113	
0.02251	7.93770	-0.08760	0.56585	
0.02300	13.67500	-0.08158	0.58279	
0.02358	19.60400	-0.07544	0.60451	
0.02428	25.79700	-0.06908	0.63299	
0.15487	112.06000	0.01894	0.45116	
0.16053	116.52000	0.02342	0.44109	
0.16587	120.89000	0.02777	0.43358	
0.17093	125.20000	0.03202	0.42785	
0.17578	129.46000	0.03617	0.42341	
0.18044	133.67000	0.04024	0.41990	
0.18494	137.86000	0.04425	0.41711	
0.18931	142.02000	0.04819	0.41487	
0.01614	-132.68000	-0.26499	0.45227	560. 0 psia
0.01642	-123.56000	-0.25090	0.45175	
0.01672	-114.16000	-0.23690	0.45339	
0.01704	-104.44000	-0.22297	0.45594	
0.01739	-94.38000	-0.20905	0.45987	
0.01776	-83.99600	-0.19515	0.46389	
0.01816	-73.24900	-0.18123	0.46789	
0.01860	-62.13900	-0.16730	0.47269	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb°F)	CTAB (Btu/lb°F)	
0.01908	-50.65300	-0.15333	0.47772	560. 0 psia
0.01962	-38.77900	-0.13931	0.48237	
0.02024	-26.48900	-0.12522	0.49444	
0.02096	-13.74200	-0.11101	0.52008	
0.02129	-8.49730	-0.10528	0.52913	
0.02164	-3.15670	-0.09950	0.53930	
0.02203	2.28760	-0.09367	0.54980	
0.02246	7.85570	-0.08777	0.56372	
0.02295	13.56900	-0.08176	0.58121	
0.02352	19.46600	-0.07567	0.60070	
0.02420	25.60600	-0.06937	0.62838	
0.14459	110.42000	0.01671	0.46920	
0.15050	115.03000	0.02136	0.45479	
0.15600	119.53000	0.02583	0.44450	
0.16117	123.93000	0.03017	0.43676	
0.16609	128.27000	0.03440	0.43092	
0.17079	132.55000	0.03855	0.42635	
0.17531	136.80000	0.04261	0.42272	
0.17968	141.01000	0.04660	0.41981	
0.01614	-132.65000	-0.26503	0.45165	580. 0 psia
0.01642	-123.53000	-0.25094	0.45361	
0.01672	-114.13000	-0.23695	0.45249	
0.01704	-104.41000	-0.22302	0.45492	
0.01738	-94.36300	-0.20911	0.45839	
0.01775	-83.97300	-0.19521	0.46348	
0.01815	-73.23000	-0.18130	0.46823	
0.01859	-62.12500	-0.16737	0.47278	
0.01907	-50.64600	-0.15341	0.47800	
0.01961	-38.78000	-0.13940	0.48184	
0.02023	-26.50100	-0.12532	0.49444	
0.02094	-13.77000	-0.11113	0.52002	
0.02126	-8.53410	-0.10540	0.52916	
0.02161	-3.20440	-0.09964	0.53849	
0.02200	2.22520	-0.09383	0.54871	
0.02242	7.77610	-0.08795	0.56115	
0.02291	13.46600	-0.08198	0.57672	
0.02346	19.33200	-0.07590	0.59587	
0.02412	25.42500	-0.06964	0.62228	
0.02493	31.84900	-0.06312	0.65722	
0.14084	113.42000	0.01920	0.47223	
0.14657	118.06000	0.02383	0.45780	
0.15190	122.59000	0.02829	0.44740	
0.15692	127.02000	0.03261	0.43963	
0.16169	131.39000	0.03683	0.43367	
0.16625	135.70000	0.04096	0.42904	
0.17063	139.97000	0.04501	0.42530	
0.01613	-132.61000	-0.26507	0.45199	600. 0 psia
0.01642	-123.50000	-0.25098	0.45194	

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	CTAB (Btu/lb °F)
0.01672	-114.09000	-0.23740	0.45351
0.01704	-104.38000	-0.22307	0.45424
0.01738	-94.33700	-0.20916	0.45817
0.01775	-83.95000	-0.19527	0.46342
0.01815	-73.21100	-0.18136	0.46820
0.01858	-62.11000	-0.16744	0.47241
0.01906	-50.63800	-0.15348	0.47732
0.01960	-38.78000	-0.13949	0.48209
0.02021	-26.51300	-0.12542	0.49459
0.02092	-13.79800	-0.11125	0.50829
0.02124	-8.57140	-0.10554	0.52776
0.02158	-3.25240	-0.09978	0.53778
0.02196	2.16410	-0.09398	0.54729
0.02239	7.69570	-0.08812	0.56016
0.02286	13.36700	-0.08218	0.57487
0.02340	19.20100	-0.07613	0.59331
0.02404	25.25100	-0.06992	0.61696
0.02482	31.60500	-0.06346	0.66459
0.13143	111.64000	0.01692	0.49559
0.13749	116.48000	0.02174	0.47467
0.14303	121.15000	0.02634	0.46032
0.14819	125.70000	0.03078	0.44996
0.15305	130.16000	0.03509	0.44219
0.15767	134.55000	0.03930	0.43618
0.16210	138.89000	0.04341	0.43142

600. 0 psia

Figure 9 . CP-34 Superheated Fluid Properties II (Cont'd)

Line No.	P (psia)	T (°F)	VLIQ (ft^3/lb)	VVAP (ft^3/lb)	HLIQ (Btu/lb)	HVAP (Btu/lb)
00010	1045.43	550.0	.02176	0.42432	549.5	1191.2
00020	1011.75	546.0	.02163	.44018	544.4	1192.5
00030	978.90	542.0	.02151	.45665	539.3	1193.7
00040	946.88	538.0	.02140	.47377	534.2	1194.8
00050	915.66	534.0	.02129	.49155	529.2	1195.9
00060	885.23	530.0	.02118	.51004	524.3	1196.9
00070	855.58	526.0	.02107	.52926	519.3	1197.8
00080	826.69	522.0	.02097	.54926	514.4	1198.6
00090	798.55	518.0	.02086	.57006	509.6	1199.4
00100	771.15	514.0	.02076	.59173	504.7	1200.2
00110	744.47	510.0	.02067	.61429	499.9	1200.8
00120	718.50	506.0	.02057	.63779	495.1	1201.4
00130	693.23	502.0	.02048	.66228	490.3	1202.0
00140	668.65	498.0	.02039	.68782	485.6	1202.5
00150	644.73	494.0	.02030	.71445	480.8	1202.9
00160	621.48	490.0	.02021	.74224	476.1	1203.3
00170	598.87	486.0	.02013	.77124	471.5	1203.7
00180	576.90	482.0	.02004	.80152	466.8	1204.0
00190	555.55	478.0	.01996	.83315	462.2	1204.2
00200	534.81	474.0	.01988	.86621	457.5	1204.4
00210	514.67	470.0	.01980	.90076	452.9	1204.6
00220	495.12	466.0	.01973	.93689	448.4	1204.7
00230	476.14	462.0	.01965	.97469	443.8	1204.8
00240	457.73	458.0	.01958	1.01425	439.3	1204.8
00250	439.87	454.0	.01950	1.05567	434.7	1204.8
00260	422.55	450.0	.01943	1.09905	430.2	1204.7
00270	405.76	446.0	.01936	1.14452	425.7	1204.6
00280	389.49	442.0	.01929	1.19217	421.3	1204.5
00290	373.72	438.0	.01923	1.24216	416.8	1204.3
00300	358.46	434.0	.01916	1.29460	412.4	1204.1
00310	343.67	430.0	.01909	1.34965	407.9	1203.9
00320	329.369	426.0	.01903	1.4075	403.5	1203.6
00330	315.529	422.0	.01897	1.4682	399.1	1203.3
00340	302.143	418.0	.01890	1.5320	394.7	1202.9
00350	289.201	414.0	.01884	1.5991	390.3	1202.6
00360	276.694	410.0	.01878	1.6697	386.0	1202.1
00370	264.611	406.0	.01872	1.7441	381.6	1201.7
00380	252.942	402.0	.01867	1.8223	377.3	1201.2
00390	241.677	398.0	.01861	1.9048	372.9	1200.7
00400	230.807	394.0	.01855	1.9917	368.6	1200.2
00410	220.321	390.0	.01850	2.0833	364.3	1199.6
00420	210.211	386.0	.01844	2.1801	360.0	1199.0
00430	200.467	382.0	.01839	2.2821	355.7	1198.4
00440	191.080	378.0	.01834	2.3900	351.4	1197.7
00450	182.040	374.0	.01829	2.5039	347.2	1197.0
00460	173.339	370.0	.01823	2.6244	342.9	1196.3

Figure 10 . Water Saturated Fluid Properties -- Pressure, Temperature, Specific Volume Liquid, Specific Volume Vapor, Enthalpy Liquid, and Enthalpy Vapor*

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*This file is not used when CP-34 is the working fluid.

Line No.	P (psia)	T (°F)	VLIQ (ft^3/lb)	VVAP (ft^3/lb)	HLIQ (Btu/lb)	HVAP (Btu/lb)
00470	164.968	366.0	.01818	2.7519	338.7	1195.6
00480	156.917	362.0	.01813	2.8868	334.4	1194.8
00490	149.179	358.0	.01809	3.0298	330.2	1194.0
00500	141.744	354.0	.01804	3.1812	326.0	1193.2
00510	134.604	350.0	.01799	3.3418	321.8	1192.3
00520	127.751	346.0	.01794	3.5122	317.6	1191.4
00530	121.177	342.0	.01790	3.6931	313.4	1190.5
00540	114.873	338.0	.01785	3.8853	309.2	1189.6
00550	108.832	334.0	.01781	4.0896	305.0	1188.7
00560	103.045	330.0	.01776	4.3069	300.8	1187.7
00570	97.506	326.0	.01772	4.5382	296.6	1186.7
00580	92.205	322.0	.01768	4.7846	292.5	1185.7
00590	87.137	318.0	.01764	5.0471	288.3	1184.7
00600	82.293	314.0	.01759	5.3272	284.2	1183.6
00610	77.667	310.0	.01755	5.6260	280.0	1182.5
00620	73.251	306.0	.01751	5.9452	275.9	1181.4
00630	69.038	302.0	.01747	6.2864	271.8	1180.3
00640	65.021	298.0	.01743	6.6513	267.7	1179.2
00650	61.194	294.0	.01739	7.0419	263.5	1178.0
00660	57.550	290.0	.01736	7.4603	259.4	1176.8
00670	54.083	286.0	.01732	7.9089	255.3	1175.6
00680	50.786	282.0	.01728	8.3902	251.2	1174.4
00690	47.653	278.0	.017246	8.907	247.13	1173.2
00700	44.678	274.0	.017210	9.462	243.03	1171.9
00710	41.856	270.0	.017175	10.060	238.95	1170.6
00720	39.179	266.0	.017140	10.703	234.87	1169.3
00730	36.644	262.0	.017106	11.395	230.79	1168.0
00740	34.243	258.0	.017072	12.142	226.72	1166.7
00750	31.972	254.0	.017039	12.948	222.65	1165.4
00760	29.825	250.0	.017006	13.819	218.59	1164.0
00770	27.797	246.0	.016974	14.761	214.53	1162.7
00780	25.883	242.0	.016942	15.780	210.48	1161.3
00790	24.079	238.0	.016910	16.884	206.42	1159.9
00800	22.379	234.0	.016880	18.082	202.38	1158.5
00810	20.779	230.0	.016849	19.381	198.33	1157.1
00820	18.912	225.0	.016812	21.166	193.28	1155.3
00830	17.186	220.0	.016775	23.148	188.23	1153.4
00840	15.592	215.0	.016740	25.355	183.19	1151.6
00850	14.123	210.0	.016705	27.816	178.15	1149.7
00860	12.770	205.0	.016670	30.564	173.12	1147.9
00870	11.526	200.0	.016637	33.639	168.09	1146.0
00880	10.385	195.0	.016604	37.086	163.06	1144.0
00890	9.340	190.0	.016572	40.957	158.04	1142.1
00900	8.384	185.0	.016541	45.313	153.02	1140.2
00910	7.511	180.0	.016510	50.225	148.00	1138.2
00920	6.7159	175.0	.016480	55.77	142.99	1136.2
00930	5.9926	170.0	.016451	62.06	137.97	1134.2
00940	5.3361	165.0	.016423	69.18	132.96	1132.2

Figure 10 . Water Saturated Fluid Properties (Cont'd)

Line No.	P (psia)	T (°F)	VLIQ (ft^3/lb)	VVAP (ft^3/lb)	HLIQ (Btu/lb)	HVAP (Btu/lb)
00950	4.7414	160.0	.016395	77.29	127.96	1130.2
00960	4.2036	155.0	.016369	86.52	122.95	1128.2
00970	3.7184	150.0	.016343	97.07	117.95	1126.1
00980	3.2816	145.0	.016317	109.14	112.95	1124.0
00990	2.8892	140.0	.016293	123.0	107.95	1122.0
01000	2.5375	135.0	.016270	138.94	102.95	1119.9
01010	2.2230	130.0	.016247	157.33	97.96	1117.8
01020	1.9424	125.0	.016225	178.60	92.96	1115.7
01030	1.6927	120.0	.016204	203.26	87.97	1113.6
01040	1.4711	115.0	.016184	231.94	82.97	1111.5
01050	1.2750	110.0	.016165	265.39	77.98	1109.3
01060	1.1017	105.0	.016147	304.50	72.99	1107.2
01070	.94924	100.0	.016130	350.4	67.999	1105.1
01080	.81534	95.0	.016114	404.4	63.008	1102.9
01090	.69813	90.0	.016099	468.1	58.018	1100.8
01100	.59583	85.0	.016085	543.6	53.027	1098.6
01110	.50683	80.0	.016072	633.3	48.037	1096.4
01120	.42964	75.0	.016060	740.3	43.045	1094.3
01130	.36292	70.0	.016050	868.4	38.052	1092.1
01140	.30545	65.0	.016041	1022.1	33.057	1089.9
01150	.25611	60.0	.016033	1207.6	28.060	1087.7

Figure 10. Water Saturated Fluid Properties (Cont'd)

Line No.												
00010	10.	15.	20.	25.	30.	35.	40.	50.	60.	70.	80.	PTAB(psia)
00020	90.	100.	110.	120.	140.	160.	180.	200.	220.	240.	260.	
00030	280.	300.	320.	340.	360.	400.	440.	480.	520.	560.	600.	
00040	650.	700.	750.	800.	850.	900.	950.	1000.	.0	.0	.0	
00050	200.	220.	240.	260.	280.	300.	320.	340.	360.	380.		TTAB(°F)
00060	400.	420.	440.	460.	480.	500.	520.	540.	560.	580.		
00070	600.	620.	640.	660.	680.	700.	720.	740.	760.	780.		
00080	800.	820.	840.	.0	.0	.0	.0	.0	.0	.0		

Figure 11. Water Superheated Fluid Properties -- Pressure and Temperature*

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
00010	77.36	1453.3	2.1167	76.17	1443.3	2.1089	10.0 psia
00020	74.98	1433.4	2.1011	73.78	1423.4	2.0931	
00030	72.59	1413.5	2.0851	71.39	1403.7	2.0769	
00040	70.20	1393.8	2.0687	69.00	1384.0	2.0603	
00050	67.81	1374.3	2.0518	66.61	1364.6	2.0432	
00060	65.42	1354.9	2.0345	64.22	1345.2	2.0256	
00070	63.03	1335.5	2.0166	61.83	1325.9	2.0074	
00080	60.63	1316.4	1.9981	59.44	1306.8	1.9887	
00090	58.24	1297.3	1.9790	57.04	1287.8	1.9692	
00100	55.84	1278.3	1.9592	54.64	1268.8	1.9491	
00110	53.44	1259.4	1.9387	52.24	1250.0	1.9281	
00120	51.03	1240.6	1.9173	49.83	1231.2	1.9062	
00130	48.62	1221.8	1.8949	47.41	1212.4	1.8834	
00140	46.20	1203.1	1.8715	44.98	1193.7	1.8593	
00150	43.77	1184.3	1.8468	42.54	1174.9	1.8339	
00160	41.32	1165.5	1.8206	40.08	1156.0	1.8070	

Figure 12. Water Superheated Fluid Properties -- Specific Volume, Enthalpy, and Entropy* (continued on following pages)

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*This file is not used when running with CP-34, as the working fluid.

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
00170	38.84	1143.6	1.7928	.0	.0	.0	10.0 psia
00180	51.557	1453.1	2.0719	50.760	1443.1	2.0641	
00190	49.964	1433.2	2.0563	49.167	1423.2	2.0483	
00200	48.370	1413.3	2.0403	47.573	1403.4	2.0321	
00210	46.775	1393.6	2.0238	45.978	1383.8	2.0155	
00220	45.180	1374.0	2.0070	44.382	1364.3	1.9983	
00230	43.584	1354.6	1.9896	42.785	1344.9	1.9807	
00240	41.986	1335.2	1.9717	41.187	1325.6	1.9625	
00250	40.387	1316.0	1.9532	39.587	1306.4	1.9437	
00260	38.786	1296.9	1.9340	37.985	1287.3	1.9242	15.0 psia
00270	37.182	1277.8	1.9142	36.379	1268.3	1.9040	
00280	35.575	1258.8	1.8935	34.770	1249.4	1.8829	
00290	33.963	1239.9	1.8720	33.155	1230.4	1.8609	
00300	32.345	1221.0	1.8495	31.532	1211.5	1.8378	
00310	30.717	1202.0	1.8258	29.899	1192.5	1.8134	
00320	29.078	1183.0	1.8007	28.252	1173.5	1.7876	
00330	27.421	1163.9	1.7741	26.584	1154.2	1.7601	
00340	.01664	168.09	.2940	.0	.0	.0	
00350	38.654	1452.9	2.0401	38.056	1442.9	2.0323	
00360	37.458	1432.9	2.0244	36.859	1423.0	2.0165	
00370	36.261	1413.1	2.0084	35.662	1403.2	2.0003	
00380	35.064	1393.4	1.9920	34.465	1383.5	1.9836	
00390	33.865	1373.8	1.9751	33.266	1364.0	1.9664	
00400	32.666	1354.3	1.9577	32.066	1344.6	1.9488	
00410	31.466	1334.9	1.9397	30.865	1325.2	1.9305	
00420	30.264	1315.6	1.9212	29.662	1306.0	1.9117	
00430	29.060	1296.4	1.9020	28.457	1286.9	1.8921	20.0 psia
00440	27.853	1277.3	1.8821	27.249	1267.8	1.8718	
00450	26.643	1258.3	1.6813	26.036	1248.7	1.8506	
00460	25.428	1239.2	1.8397	24.818	1229.7	1.8285	
00470	24.206	1220.1	1.8170	23.592	1210.6	1.8052	
00480	22.976	1201.0	1.7930	22.356	1191.4	1.7805	
00490	21.732	1181.7	1.7676	21.104	1172.0	1.7543	
00500	20.471	1162.2	1.7406	.01678	188.24	.3241	
00510	.01664	168.11	.2940	.0	.0	.0	
00520	30.902	1452.8	2.0154	30.433	1442.7	2.0076	
00530	29.954	1432.7	1.9997	29.475	1422.8	1.9918	
00540	28.996	1412.9	1.9837	28.516	1403.0	1.9755	
00550	28.036	1393.1	1.9672	27.557	1383.3	1.9588	
00560	27.077	1373.5	1.9503	26.596	1363.7	1.9417	
00570	26.116	1354.0	1.9329	25.635	1344.3	1.9240	
00580	25.153	1334.6	1.9149	24.672	1324.9	1.9057	25.0 psia
00590	24.190	1315.3	1.8963	23.707	1305.6	1.8868	
00600	23.224	1296.0	1.8771	22.740	1286.4	1.8672	
00610	22.256	1276.8	1.8571	21.770	1267.3	1.8468	
00620	21.284	1257.7	1.8362	20.796	1248.1	1.8255	
00630	20.307	1238.5	1.8145	19.816	1228.9	1.8032	
00640	19.323	1219.3	1.7916	18.828	1209.6	1.7796	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
00650	18.330	1200.0	1.7674	17.829	1190.2	1.7547	25.0 psia
00660	17.324	1180.4	1.7417	16.814	1170.5	1.7281	
00670	.01693	208.45	.3533	.01678	188.25	.3241	
00680	.01664	168.12	.2940	.0	.0	.0	
00690	25.751	1452.6	1.9952	25.351	1442.5	1.9874	30.0 psia
00700	24.952	1432.5	1.9795	24.552	1422.6	1.9715	
00710	24.152	1412.6	1.9635	23.752	1402.7	1.9553	
00720	23.352	1392.9	1.9470	22.951	1383.0	1.9386	
00730	22.551	1373.2	1.9300	22.105	1363.4	1.9214	
00740	21.749	1353.7	1.9126	21.347	1344.0	1.9037	
00750	20.945	1334.2	1.8946	20.543	1324.6	1.8853	
00760	20.140	1314.9	1.8760	19.737	1305.2	1.8664	
00770	19.333	1295.6	1.8567	18.929	1286.0	1.8467	
00780	18.524	1276.3	1.8366	18.118	1266.7	1.8262	
00790	17.710	1257.1	1.8157	17.302	1247.5	1.8048	
00800	16.892	1237.8	1.7937	16.481	1228.1	1.7823	
00810	16.067	1218.4	1.7707	15.651	1208.7	1.7586	
00820	15.232	1198.9	1.7462	14.810	1189.0	1.7334	
00830	14.384	1179.1	1.7201	13.954	1169.0	1.7064	
00840	.01693	208.46	.3533	.01677	188.26	.3240	
00850	.01664	168.13	.2940	.0	.0	.0	
00860	22.064	1452.4	1.9781	21.722	1442.3	1.9703	35.0 psia
00870	21.379	1432.3	1.9624	21.036	1422.4	1.9544	
00880	20.692	1412.4	1.9463	20.349	1402.5	1.9381	
00890	20.006	1392.6	1.9298	19.662	1382.8	1.9214	
00900	19.318	1373.0	1.9129	18.974	1363.2	1.9042	
00910	18.629	1353.4	1.8954	18.285	1343.6	1.8865	
00920	17.939	1333.9	1.8774	17.594	1324.2	1.8681	
00930	17.248	1314.5	1.8587	16.902	1304.8	1.8491	
00940	16.554	1295.2	1.8393	16.207	1285.5	1.8294	
00950	15.858	1275.8	1.8192	15.509	1266.2	1.8088	
00960	15.158	1256.5	1.7982	14.806	1246.8	1.7873	
00970	14.453	1237.1	1.7761	14.098	1227.4	1.7646	
00980	13.741	1217.6	1.7528	13.382	1207.7	1.7407	
00990	13.019	1197.8	1.7281	12.654	1187.8	1.7152	
01000	12.284	1177.7	1.7017	11.909	1167.5	1.6877	
01010	.01693	208.47	.3533	.01677	188.27	.3240	
01020	.01664	168.14	.2940	.0	.0	.0	
01030	19.299	1452.2	1.9632	18.999	1442.1	1.9554	40.0 psia
01040	18.699	1432.1	1.9476	18.398	1422.1	1.9396	
01050	18.098	1412.2	1.9315	17.797	1402.3	1.9233	
01060	17.496	1392.4	1.9150	17.195	1382.5	1.9065	
01070	16.893	1372.7	1.8980	16.592	1362.9	1.8893	
01080	16.290	1353.1	1.8805	15.988	1343.3	1.8715	
01090	15.685	1333.6	1.8624	15.382	1323.9	1.8531	
01100	15.079	1314.1	1.8437	14.775	1304.4	1.8341	
01110	14.470	1294.7	1.8243	14.165	1285.0	1.8143	
01120	13.859	1275.3	1.8041	13.552	1265.6	1.7936	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
01130	13.244	1255.9	1.7830	12.934	1246.2	1.7720	
01140	12.624	1236.4	1.7608	12.311	1226.6	1.7492	
01150	11.996	1216.7	1.7373	11.679	1206.8	1.7250	
01160	11.359	1196.7	1.7123	11.036	1186.6	1.6992	40. 0 psia
01170	10.708	1176.4	1.6855	.01709	228.77	.3819	
01180	.01693	208.48	.3533	.01677	188.28	.3240	
01190	.01664	168.15	.2940	.0	.0	.0	
01200	15.428	1451.8	1.9384	15.188	1441.7	1.9306	
01210	14.947	1431.7	1.9227	14.706	1421.7	1.9147	
01220	14.465	1411.8	1.9066	14.224	1401.8	1.8984	
01230	13.982	1391.9	1.8901	13.741	1382.0	1.8816	
01240	13.499	1372.2	1.8731	13.257	1362.3	1.8643	
01250	13.015	1352.5	1.8555	12.772	1342.7	1.8465	
01260	12.529	1332.9	1.8374	12.285	1323.2	1.8280	
01270	12.041	1313.4	1.8186	11.797	1303.6	1.8089	
01280	11.552	1293.9	1.7990	11.306	1284.1	1.7890	50. 0 psia
01290	11.060	1274.3	1.7787	10.812	1264.5	1.7681	
01300	10.564	1254.7	1.7573	10.314	1244.9	1.7463	
01310	10.062	1234.9	1.7349	9.809	1225.0	1.7231	
01320	9.553	1214.9	1.7110	9.295	1204.8	1.6985	
01330	9.034	1194.5	1.6855	8.769	1184.1	1.6720	
01340	.01726	249.17	.4098	.01709	228.79	.3819	
01350	.01692	208.50	.3533	.01677	188.30	.3240	
01360	.01663	168.17	.2940	.0	.0	.0	
01370	12.848	1451.4	1.9181	12.647	1441.3	1.9103	
01380	12.446	1431.3	1.9024	12.245	1421.3	1.8944	
01390	12.043	1411.3	1.8863	11.842	1401.3	1.8780	
01400	11.640	1391.4	1.8697	11.435	1381.5	1.8612	
01410	11.236	1371.6	1.8526	11.034	1361.8	1.8439	
01420	10.831	1351.9	1.8350	10.628	1342.1	1.8260	
01430	10.425	1332.3	1.8166	10.221	1322.4	1.8075	
01440	10.017	1312.6	1.7979	9.812	1302.8	1.7882	
01450	9.606	1293.0	1.7783	9.400	1283.2	1.7681	60. 0 psia
01460	9.193	1273.3	1.7578	8.985	1263.4	1.7471	
01470	8.776	1253.5	1.7362	8.566	1243.5	1.7250	
01480	8.354	1233.5	1.7134	8.140	1223.3	1.7015	
01490	7.924	1213.1	1.6892	7.705	1202.8	1.6764	
01500	7.483	1192.2	1.6631	7.257	1181.6	1.6492	
01510	.01726	249.19	.4098	.01709	228.81	.3819	
01520	.01692	208.52	.3533	.01677	188.33	.3240	
01530	.01663	168.20	.2939	.0	.0	.0	
01540	11.005	1451.0	1.9009	10.832	1440.9	1.8931	
01550	10.659	1430.9	1.8852	10.486	1420.9	1.8771	
01560	10.313	1410.9	1.8690	10.140	1400.9	1.8608	
01570	9.967	1390.9	1.8524	9.793	1381.0	1.8439	70. 0 psia
01580	9.620	1371.1	1.8353	9.446	1361.2	1.8265	
01590	9.271	1351.3	1.8176	9.097	1341.5	1.8086	
01600	8.922	1331.6	1.7993	8.746	1321.7	1.7900	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
01610	8.570	1311.9	1.7804	8.394	1302.0	1.7706	
01620	8.217	1292.1	1.7606	8.039	1282.2	1.7504	
01630	7.860	1272.3	1.7399	7.681	1262.3	1.7292	
01640	7.500	1252.3	1.7182	7.317	1242.2	1.7068	
01650	7.133	1232.0	1.6951	6.947	1221.7	1.6830	
01660	6.759	1211.3	1.6704	6.568	1200.7	1.6574	70. 0 psia
01670	6.374	1189.9	1.6437	.01745	269.72	.4372	
01680	.01726	249.21	.4098	.01709	228.83	.3819	
01690	.01692	208.54	.3533	.01677	188.35	.3240	
01700	.01663	168.22	.2939	.0	.0	.0	
01710	9.622	1450.7	1.8860	9.471	1440.6	1.8781	
01720	9.319	1430.5	1.8702	9.168	1420.4	1.8622	
01730	9.016	1410.4	1.8540	8.864	1400.4	1.8458	
01740	8.712	1390.4	1.8374	8.560	1380.5	1.8289	
01750	8.407	1370.6	1.8202	8.254	1360.6	1.8114	
01760	8.101	1350.7	1.8025	7.948	1340.8	1.7934	
01770	7.794	1330.9	1.7842	7.640	1321.0	1.7747	
01780	7.485	1311.1	1.7651	7.330	1301.2	1.7553	
01790	7.174	1291.2	1.7452	7.018	1281.3	1.7349	80. 0 psia
01800	6.860	1271.3	1.7244	6.702	1261.2	1.7136	
01810	6.542	1251.0	1.7024	6.381	1240.8	1.6909	
01820	6.218	1230.5	1.6790	6.053	1220.0	1.6667	
01830	5.885	1209.4	1.6539	5.715	1198.6	1.6405	
01840	5.541	1187.5	1.6266	.01745	269.74	.4371	
01850	.01726	249.23	.4098	.01709	228.85	.3818	
01860	.01692	208.57	.3533	.01677	188.37	.3240	
01870	.01663	168.24	.2939	.0	.0	.0	
01880	8.547	1450.3	1.8728	8.412	1440.2	1.8649	
01890	8.277	1430.1	1.8570	8.142	1420.0	1.8489	
01900	8.007	1410.0	1.8408	7.872	1400.0	1.8325	
01910	7.736	1390.0	1.8241	7.600	1380.0	1.8156	
01920	7.464	1370.0	1.8069	7.328	1360.1	1.7981	
01930	7.192	1350.1	1.7891	7.065	1340.2	1.7800	
01940	6.917	1330.2	1.7707	6.780	1320.3	1.7612	
01950	6.642	1310.3	1.7516	6.503	1300.4	1.7417	
01960	6.363	1290.4	1.7316	6.223	1280.3	1.7212	90. 0 psia
01970	6.082	1270.2	1.7106	5.940	1260.0	1.6996	
01980	5.797	1249.8	1.6883	5.652	1239.4	1.6767	
01990	5.505	1228.9	1.6646	5.356	1218.3	1.6521	
02000	5.205	1207.5	1.6391	5.051	1196.4	1.6254	
02010	.01766	290.40	.4639	.01745	269.76	.4371	
02020	.01726	249.25	.4098	.01709	228.87	.3818	
02030	.01692	208.59	.3533	.01677	188.39	.3240	
02040	.01663	168.26	.2939	.0	.0	.0	
02050	7.687	1449.9	1.8609	7.565	1439.8	1.8531	
02060	7.443	1429.7	1.8451	7.322	1419.6	1.8371	
02070	7.200	1409.5	1.8289	7.078	1399.5	1.8206	100. 0 psia
02080	6.955	1389.5	1.8122	6.833	1379.5	1.8036	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
02090	6.710	1369.5	1.7949	6.587	1359.5	1.7861	
02100	6.464	1349.5	1.7771	6.340	1339.6	1.7680	
02110	6.216	1329.6	1.7586	6.092	1319.6	1.7491	
02120	5.967	1309.6	1.7394	5.841	1299.5	1.7294	
02130	5.715	1289.5	1.7193	5.588	1279.3	1.7088	
02140	5.460	1269.1	1.6981	5.331	1258.9	1.6870	
02150	5.200	1248.5	1.6756	5.068	1238.0	1.6638	100. 0 psia
02160	4.935	1227.4	1.6516	4.799	1216.5	1.6389	
02170	4.661	1205.5	1.6255	4.519	1194.2	1.6116	
02180	.01766	290.42	.4639	.01745	269.77	.4371	
02190	.01726	249.27	.4098	.01708	228.89	.3818	
02200	.01692	208.61	.3532	.01677	188.41	.3240	
02210	.01663	168.29	.2939	.0	.0	.0	
02220	6.983	1447.5	1.8502	6.872	1439.4	1.8424	
02230	6.761	1429.2	1.8344	6.650	1419.1	1.8263	
02240	6.539	1409.1	1.8181	6.428	1399.0	1.8098	
02250	6.316	1389.0	1.8014	6.205	1379.0	1.7928	
02260	6.093	1368.9	1.7841	5.981	1358.9	1.7752	
02270	5.868	1348.9	1.7662	5.755	1338.9	1.7570	
02280	5.642	1328.9	1.7476	5.528	1318.9	1.7381	
02290	5.414	1308.8	1.7283	5.299	1298.7	1.7183	
02300	5.184	1288.6	1.7081	5.068	1278.3	1.6975	110. 0 psia
02310	4.950	1268.1	1.6867	4.832	1257.7	1.6756	
02320	4.712	1247.2	1.6640	4.591	1236.6	1.6521	
02330	4.468	1225.8	1.6396	4.343	1214.7	1.6267	
02340	4.214	1203.5	1.6131	4.083	1191.9	1.5988	
02350	.01765	290.44	.4639	.01745	269.79	.4371	
02360	.01726	249.29	.4097	.01708	228.91	.3818	
02370	.01692	208.63	.3532	.01677	188.43	.3239	
02380	.01663	168.31	.2939	.0	.0	.0	
02390	6.3962	1447.1	1.8404	6.2946	1439.0	1.8325	
02400	6.1928	1427.8	1.8246	6.0908	1418.7	1.8165	
02410	5.9887	140[illegible].6	1.8083	5.8864	1398.5	1.7999	
02420	5.7840	1388.5	1.7915	5.6813	1378.4	1.7829	
02430	5.5784	1368.4	1.7741	5.4752	1358.4	1.7653	
02440	5.3717	1348.3	1.7562	5.2679	1338.3	1.7470	
02450	5.1637	1328.2	1.7376	5.0590	1318.1	1.7280	
02460	4.9538	1308.0	1.7182	4.8480	1297.9	1.7081	120. 0 psia
02470	4.7414	1287.6	1.6978	4.6341	1277.4	1.6872	
02480	4.5258	1267.0	1.6762	4.4163	1256.5	1.6650	
02490	4.3054	1245.9	1.6533	4.1930	1235.1	1.6412	
02500	4.0786	1224.1	1.6286	3.9619	1212.9	1.6154	
02510	3.8424	1201.4	1.6015	.01787	311.26	.4902	
02520	.01765	290.45	.4639	.01745	269.81	.4371	
02530	.01726	249.31	.4097	.01708	228.93	.3818	
02540	.01692	208.65	.3532	.01677	188.46	.3239	
02550	.01663	168.33	.2939	.0	.0	.0	
02560	5.4746	144[illegible].4	1.8230	5.3871	1438.2	1.8151	140. 0 psia

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
02570	5.2995	1428.0	1.8071	5.2117	1417.9	1.7990	
02580	5.1238	1407.7	1.7907	5.0357	1397.6	1.7824	
02590	4.9474	1387.5	1.7739	4.8588	1377.4	1.7652	
02600	4.7701	1367.3	1.7564	4.6810	1357.2	1.7475	
02610	4.5917	1347.1	1.7384	4.5020	1337.0	1.7291	
02620	4.4119	1326.8	1.7196	4.3213	1316.7	1.7099	
02630	4.2302	1306.4	1.7000	4.1385	1296.1	1.6898	
02640	4.0460	1285.8	1.6793	3.9526	1275.3	1.6686	140. 0 psia
02650	3.8582	1264.8	1.6574	3.7627	1254.1	1.6459	
02660	3.6656	1243.2	1.6340	3.5669	1232.1	1.6215	
02670	3.4661	1220.8	1.6085	3.3629	1209.2	1.5948	
02680	3.2567	1197.2	1.5804	.01787	311.29	.4902	
02690	.01765	290.49	.4639	.01745	269.85	.4370	
02700	.01726	249.35	.4097	.01708	228.97	.3818	
02710	.01692	208.69	.3532	.01677	188.50	.3239	
02720	.01663	168.38	.2939	.0	.0	.0	
02730	4.7833	1447.6	1.8078	4.7065	1437.4	1.7999	
02740	4.6295	1427.2	1.7919	4.5523	1417.0	1.7837	
02750	4.4750	1406.8	1.7755	4.3975	1396.7	1.7671	
02760	4.3199	1386.5	1.7585	4.2420	1376.4	1.7499	
02770	4.1638	1366.2	1.7410	4.0854	1356.0	1.7320	
02780	4.0066	1345.9	1.7229	3.9275	1335.7	1.7135	
02790	3.8480	1325.4	1.7039	3.7680	1315.2	1.6941	
02800	3.6874	1304.8	1.6841	3.6062	1294.4	1.6738	
02810	3.5242	1283.9	1.6632	3.4413	1273.3	1.6522	160. 0 psia
02820	3.3573	1262.5	1.6409	3.2720	1251.6	1.6291	
02830	3.1853	1240.4	1.6169	3.0967	1229.1	1.6041	
02840	3.0060	1217.4	1.5906	2.9127	1205.3	1.5764	
02850	.01811	332.32	.5161	.01787	311.33	.4902	
02860	.01765	290.52	.4638	.01745	269.89	.4370	
02870	.01726	249.39	.4097	.01708	229.01	.3817	
02880	.01692	208.73	.3532	.01677	188.54	.3239	
02890	.01663	168.42	.2938	.0	.0	.0	
02900	4.2457	1446.8	1.7944	4.1771	1436.6	1.7865	
02910	4.1084	1426.3	1.7784	4.0395	1416.1	1.7702	
02920	3.9704	1405.9	1.7619	3.9012	1395.7	1.7535	
02930	3.8318	1385.5	1.7449	3.7621	1375.3	1.7362	
02940	3.6922	1365.1	1.7273	3.6221	1354.9	1.7183	
02950	3.5515	1344.6	1.7090	3.4807	1334.4	1.6996	
02960	3.4093	1324.0	1.6900	3.3375	1313.7	1.6801	
02970	3.2651	1303.2	1.6699	3.1920	1292.6	1.6595	180. 0 psia
02980	3.1181	1282.0	1.6487	3.0433	1271.2	1.6376	
02990	2.9673	1260.2	1.6260	2.8900	1249.0	1.6140	
03000	2.8112	1237.6	1.6014	2.7304	1225.9	1.5882	
03010	2.6474	1213.8	1.5743	2.5616	1201.3	1.5596	
03020	.01811	332.35	.5160	.01787	311.36	.4901	
03030	.01765	290.56	.4638	.01741	269.92	.4370	
03040	.01725	249.43	.4096	.01708	229.05	.3817	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft³/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
03050	.01692	208.76	.3531	.01677	188.59	.3258	180. 0 psia
03060	.01663	168.47	.2938	.0	.0	.0	
03070	3.8156	1447.1	1.7824	3.7536	1435.8	1.7744	200. 0 psia
03080	3.6915	1426.5	1.7663	3.6292	1415.2	1.7581	
03090	3.5668	1405.0	1.7498	3.5041	1394.4	1.7413	
03100	3.4413	1383.5	1.7327	3.3783	1374.3	1.7239	
03110	3.3150	1364.0	1.7150	3.2513	1353.7	1.7059	
03120	3.1874	1343.4	1.6966	3.1231	1333.0	1.6871	
03130	3.0583	1322.6	1.6773	2.9938	1312.1	1.6674	
03140	2.9271	1301.5	1.6571	2.8605	1290.9	1.6465	
03150	2.7931	1280.0	1.6356	2.7247	1269.0	1.6242	
03160	2.6551	1257.9	1.6124	2.5841	1246.1	1.6001	
03170	2.5115	1234.7	1.5873	2.4369	1222.6	1.5737	
03180	2.3598	1211.1	1.5593	.01836	353.58	.5415	
03190	.01811	332.36	.5130	.01787	311.39	.4901	
03200	.01765	291.59	.4657	.01744	269.96	.4369	
03210	.01725	249.46	.4096	.01708	229.09	.3817	
03220	.01692	208.82	.3531	.01676	188.63	.3258	
03230	.01663	168.51	.2938	.0	.0	.0	
03240	3.4636	1445.5	1.7714	3.4071	1435.0	1.7634	220. 0 psia
03250	3.3504	1424.7	1.7553	3.2936	1414.1	1.7471	
03260	3.2365	1404.1	1.7387	3.1792	1393.8	1.7302	
03270	3.1218	1383.5	1.7216	3.0642	1373.2	1.7128	
03280	3.0062	1362.9	1.7038	2.9480	1352.5	1.6946	
03290	2.8894	1342.1	1.6852	2.8305	1331.7	1.6757	
03300	2.7710	1321.2	1.6658	2.7111	1310.6	1.6557	
03310	2.6505	1299.9	1.6453	2.5892	1289.0	1.6346	
03320	2.5270	1277.0	1.6235	2.4638	1266.9	1.6120	
03330	2.3994	1255.4	1.5995	2.3335	1243.7	1.5873	
03340	2.2659	1231.7	1.5741	2.1962	1219.3	1.5601	
03350	2.1240	1208.3	1.5453	.01836	353.61	.5415	
03360	.01811	332.41	.5129	.01787	311.42	.4900	
03370	.01765	290.63	.4657	.01744	270.00	.4369	
03380	.01725	249.54	.4096	.01708	229.15	.3816	
03390	.01691	208.86	.3531	.01676	188.66	.3258	
03400	.01663	168.56	.2938	.0	.0	.0	
03410	3.1704	1441.5	1.7614	3.1183	1433.2	1.7534	240. 0 psia
03420	3.0661	1423.0	1.7452	3.0137	1413.5	1.7370	
03430	2.9612	1403.2	1.7286	2.9085	1392.8	1.7200	
03440	2.8555	1382.5	1.7113	2.8024	1372.1	1.7025	
03450	2.7489	1361.8	1.6935	2.6952	1351.3	1.6842	
03460	2.6411	1341.9	1.6748	2.5866	1330.3	1.6651	
03470	2.5316	1319.7	1.6552	2.4760	1309.6	1.6450	
03480	2.4199	1298.2	1.6345	2.3629	1287.2	1.6236	
03490	2.3051	1276.0	1.6123	2.2462	1264.6	1.6006	
03500	2.1860	1253.0	1.5885	2.1243	1241.0	1.5754	
03510	2.0608	1228.6	1.5618	1.9951	1215.8	1.5474	
03520	1.9268	1202.4	1.5320	.01836	353.63	.5414	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
03530	.01810	332.44	.5159	.01786	311.46	.4900	
03540	.01764	290.66	.4637	.01744	270.03	.4369	
03550	.01725	249.54	.4095	.01708	229.17	.3816	240.0 psia
03560	.01691	208.90	.3530	.01676	188.72	.3238	
03570	.01662	168.60	.2937	.0	.0	.0	
03580	2.9222	1443.7	1.7521	2.8740	1433.4	1.7441	
03590	2.8256	1423.0	1.7359	2.7770	1412.6	1.7276	
03600	2.7283	1402.3	1.7192	2.6794	1391.9	1.7106	
03610	2.6302	1381.5	1.7019	2.5808	1371.1	1.6930	
03620	2.5312	1360.6	1.6839	2.4812	1350.1	1.6746	
03630	2.4309	1339.6	1.6651	2.3801	1329.0	1.6554	
03640	2.3289	1318.2	1.6453	2.2771	1307.4	1.6350	
03650	2.2246	1296.4	1.6244	2.1713	1285.3	1.6133	
03660	2.1172	1274.0	1.6019	2.0619	1262.4	1.5899	260.0 psia
03670	2.0053	1250.4	1.5774	1.9471	1238.2	1.5642	
03680	1.8870	1225.5	1.5502	1.8246	1212.2	1.5353	
03690	.01864	375.11	.5666	.01836	353.66	.5414	
03700	.01810	332.46	.5159	.01786	311.49	.4899	
03710	.01764	290.70	.4636	.01744	270.07	.4368	
03720	.01725	249.58	.4095	.01707	229.21	.3816	
03730	.01691	208.95	.3530	.01676	188.76	.3237	
03740	.01662	168.65	.2937	.0	.0	.0	
03750	2.7095	1443.0	1.7435	2.6645	1432.5	1.7355	
03760	2.6194	1422.1	1.7273	2.5741	1411.7	1.7189	
03770	2.5286	1401.3	1.7105	2.4829	1390.4	1.7019	
03780	2.4371	1380.5	1.6931	2.3909	1370.0	1.6841	
03790	2.3445	1357.5	1.6750	2.2978	1348.9	1.6650	
03800	2.2507	1338.3	1.6561	2.2031	1327.6	1.6462	
03810	2.1551	1316.8	1.6361	2.1065	1305.6	1.6257	
03820	2.0572	1294.7	1.6149	2.0070	1283.4	1.6037	
03830	1.9559	1271.9	1.5920	1.9037	1260.0	1.5798	280.0 psia
03840	1.8501	1247.9	1.5670	1.7948	1235.3	1.5535	
03850	1.7376	1222.2	1.5391	1.6780	1208.6	1.5238	
03860	.01863	375.13	.5666	.01835	353.69	.5414	
03870	.01810	332.49	.5158	.01786	311.52	.4899	
03880	.01764	290.73	.4636	.01744	270.11	.4368	
03890	.01725	249.62	.4094	.01707	229.25	.3815	
03900	.01691	208.99	.3530	.01676	188.81	.3237	
03910	.01662	168.70	.2937	.0	.0	.0	
03920	2.5251	1442.2	1.7355	2.4830	1431.7	1.7274	
03930	2.4407	1421.3	1.7192	2.3982	1410.9	1.7108	
03940	2.3556	1400.4	1.7023	2.3127	1389.9	1.6937	
03950	2.2696	1379.4	1.6848	2.2263	1368.9	1.6758	
03960	2.1827	1358.3	1.6666	2.1388	1347.7	1.6572	300.0 psia
03970	2.0945	1337.0	1.6476	2.0497	1326.2	1.6376	
03980	2.0044	1315.2	1.6274	1.9585	1304.2	1.6169	
03990	1.9119	1292.9	1.6059	1.8645	1281.4	1.5946	
04000	1.8161	1269.7	1.5827	1.7665	1257.7	1.5703	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
04010	1.7154	1245.2	1.5572	1.6627	1232.3	1.5433	
04020	1.6079	1218.9	1.5286	1.5506	1204.8	1.5127	
04030	.01863	375.15	.5665	.01835	353.71	.5413	
04040	.01810	332.52	.5158	.01786	311.55	.4899	300. 0 psia
04050	.01764	290.77	.4635	.01744	270.14	.4367	
04060	.01725	249.66	.4094	.01707	229.29	.3815	
04070	.01691	209.03	.3530	.01676	188.85	.3237	
04080	.01662	168.74	.2937	.0	.0	.0	
04090	2.3638	1441.4	1.7279	2.3241	1430.9	1.7198	
04100	2.2843	1420.5	1.7116	2.2443	1410.0	1.7032	
04110	2.2041	1399.5	1.6946	2.1637	1389.0	1.6859	
04120	2.1231	1378.4	1.6771	2.0823	1367.8	1.6680	
04130	2.0411	1357.2	1.6588	1.9996	1346.5	1.6493	
04140	1.9577	1335.7	1.6396	1.9154	1324.8	1.6295	
04150	1.8725	1313.7	1.6192	1.8290	1302.5	1.6085	
04160	1.7848	1291.1	1.5975	1.7397	1279.5	1.5859	
04170	1.6936	1267.5	1.5739	1.6462	1255.2	1.5612	320. 0 psia
04180	1.5974	1242.5	1.5478	1.5468	1229.3	1.5336	
04190	1.4940	1215.5	1.5184	.01893	396.91	.5915	
04200	.01863	375.17	.5605	.01835	353.74	.5413	
04210	.01809	332.55	.5157	.01786	311.58	.4898	
04220	.01764	290.80	.4635	.01743	270.18	.4367	
04230	.01725	249.70	.4094	.01707	229.34	.3815	
04240	.01691	209.07	.3529	.01676	188.90	.3237	
04250	.01662	168.79	.2936	.0	.0	.0	
04260	2.2215	1440.6	1.7208	2.1840	1430.1	1.7127	
04270	2.1463	1419.6	1.7044	2.1085	1409.1	1.6960	
04280	2.0705	1398.5	1.6874	2.0323	1388.0	1.6787	
04290	1.9939	1377.4	1.6697	1.9552	1366.7	1.6606	
04300	1.9161	1356.0	1.6513	1.8768	1345.2	1.6418	
04310	1.8370	1334.3	1.6320	1.7968	1323.3	1.6219	
04320	1.7561	1312.2	1.6114	1.7147	1300.8	1.6006	
04330	1.6725	1289.3	1.5894	1.6294	1277.5	1.5777	340. 0 psia
04340	1.5853	1265.3	1.5654	1.5399	1252.8	1.5525	
04350	1.4930	1239.8	1.5388	1.4443	1226.2	1.5242	
04360	1.3933	1212.0	1.5086	.01893	396.92	.5914	
04370	.01863	375.20	.5664	.01835	353.76	.5412	
04380	.01809	332.58	.5157	.01785	311.62	.4898	
04390	.01764	290.84	.4635	.01743	270.22	.4367	
04400	.01724	249.74	.4093	.01707	229.38	.3814	
04410	.01691	209.12	.3529	.01676	188.94	.3236	
04420	.01662	168.83	.2936	.0	.0	.0	
04430	2.0950	1437.8	1.7141	2.0594	1429.3	1.7059	
04440	2.0237	1418.7	1.6976	1.9878	1408.2	1.6891	
04450	1.9517	1397.6	1.6805	1.9154	1387.0	1.6717	360. 0 psia
04460	1.8789	1375.3	1.6628	1.8421	1365.6	1.6536	
04470	1.8050	1354.8	1.6443	1.7676	1344.0	1.6346	
04480	1.7297	1333.0	1.6247	1.6914	1321.9	1.6145	
04490	1.6525	1311.6	1.6040	1.6129	1299.1	1.5931	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
04500	1.5726	1287.4	1.5817	1.5314	1275.4	1.5598	360. 0 psia
04510	1.4890	1263.1	1.5573	1.4454	1250.3	1.5441	
04520	1.4001	1237.0	1.5301	1.3529	1223.1	1.5152	
04530	1.3034	1208.4	1.4990	.01895	396.94	.5914	
04540	.01862	375.22	.5664	.01836	353.79	.5412	
04550	.01809	332.61	.5156	.01785	311.65	.4897	
04560	.01763	290.87	.4634	.01743	270.25	.4366	
04570	.01724	249.78	.4093	.10707	229.42	.3814	
04580	.01691	209.16	.3529	.01676	188.98	.3256	
04590	.01662	168.88	.2936	.0	.0	.0	
04600	1.8798	1439.3	1.7016	1.8476	1427.7	1.6933	400. 0 psia
04610	1.8151	1417.0	1.6850	1.7825	1406.4	1.6764	
04620	1.7497	1395.7	1.6678	1.7167	1385.0	1.6589	
04630	1.6835	1374.2	1.6499	1.6499	1363.4	1.6406	
04640	1.6161	1352.5	1.6311	1.5819	1341.4	1.6213	
04650	1.5472	1330.3	1.6113	1.5120	1319.0	1.6009	
04660	1.4763	1307.4	1.5901	1.4399	1295.7	1.5789	
04670	1.4026	1283.6	1.5672	1.3644	1271.2	1.5549	
04680	1.3249	1258.4	1.5420	1.2841	1245.1	1.5282	
04690	1.2416	1231.2	1.5136	1.1970	1216.5	1.4978	
04700	.01926	419.04	.6160	.01892	396.98	.5912	
04710	.01862	375.27	.5663	.01834	353.84	.5411	
04720	.01809	332.67	.5155	.01785	311.71	.4896	
04730	.01763	290.94	.4633	.01743	270.33	.4366	
04740	.01724	249.85	.4092	.01706	229.50	.3813	
04750	.01690	209.24	.3528	.01675	189.07	.3236	
04760	.01662	168.97	.2935	.0	.0	.0	
04770	1.7038	1436.7	1.6901	1.6742	1426.0	1.6819	440. 0 psia
04780	1.6445	1415.3	1.6734	1.6146	1404.6	1.6649	
04790	1.5845	1393.8	1.6561	1.5541	1383.0	1.6472	
04800	1.5235	1372.1	1.6380	1.4926	1361.1	1.6286	
04810	1.4614	1350.1	1.6190	1.4295	1338.9	1.6091	
04820	1.3977	1327.5	1.5988	1.3652	1316.0	1.5882	
04830	1.3319	1304.2	1.5772	1.2986	1292.1	1.5657	
04840	1.2632	1279.7	1.5537	1.2274	1266.9	1.5410	
04850	1.1903	1253.6	1.5276	1.1517	1239.7	1.5132	
04860	1.1113	1225.1	1.4979	1.0686	1209.6	1.4812	
04870	.01925	419.07	.6159	.01892	397.02	.5911	
04880	.01861	375.31	.5662	.01834	353.90	.5410	
04890	.01808	332.73	.5154	.01785	311.78	.4896	
04900	.01763	291.01	.4633	.01742	270.40	.4365	
04910	.01724	249.93	.4092	.01706	229.58	.3813	
04920	.01690	209.33	.3527	.01675	189.16	.3235	
04930	.01661	169.06	.2935	.0	.0	.0	
04940	1.5571	1435.1	1.6797	1.5294	1424.3	1.6713	480. 0 psia
04950	1.5023	1413.6	1.6628	1.4746	1402.7	1.6542	
04960	1.4467	1391.9	1.6453	1.4186	1381.0	1.6363	
04970	1.3902	1369.9	1.6270	1.3615	1358.8	1.6176	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
04980	1.3324	1347.6	1.6078	1.3030	1336.2	1.5977	
04990	1.2731	1324.7	1.5873	1.2426	1312.9	1.5765	
05000	1.2115	1300.3	1.5652	1.1796	1288.5	1.5534	
05010	1.1468	1275.7	1.5410	1.1129	1262.4	1.5279	
05020	1.0777	1248.6	1.5139	1.0469	1234.1	1.4990	
05030	1.0021	1218.8	1.4828	.01961	441.54	.6404	
05040	.01924	419.09	.6158	.01891	397.05	.5910	480. 0 psia
05050	.01861	375.36	.5661	.01833	353.95	.5409	
05060	.01808	332.79	.5154	.01784	311.84	.4895	
05070	.01762	291.08	.4652	.01742	270.48	.4364	
05080	.01723	250.01	.4091	.01706	229.66	.3812	
05090	.01690	209.41	.3527	.01675	189.25	.3234	
05100	.01661	169.15	.2934	.0	.0	.0	
05110	1.4330	1433.5	1.6699	1.4075	1422.7	1.6615	
05120	1.3819	1411.8	1.6530	1.3561	1400.9	1.6442	
05130	1.3301	1389.9	1.6353	1.3036	1378.9	1.6262	
05140	1.2773	1367.8	1.6168	1.2504	1356.5	1.6072	
05150	1.2232	1345.1	1.5973	1.1956	1333.6	1.5871	
05160	1.1675	1321.8	1.5765	1.1388	1309.8	1.5654	
05170	1.1094	1297.4	1.5533	1.0792	1284.7	1.5418	
05180	1.0481	1271.5	1.5290	1.0157	1257.8	1.5154	
05190	.9820	1243.5	1.5009	.9466	1228.3	1.4853	520. 0 psia
05200	.9090	1212.1	1.4682	.01960	441.55	.6403	
05210	.01924	419.12	.6156	.01891	397.09	.5909	
05220	.01861	375.40	.5659	.01833	354.00	.5408	
05230	.01807	332.85	.5153	.01784	311.91	.4894	
05240	.01762	291.15	.4651	.01742	270.55	.4363	
05250	.01723	250.09	.4090	.01706	229.74	.3812	
05260	.01690	209.50	.3526	.01675	189.33	.3234	
05270	.01661	169.24	.2934	.0	.0	.0	
05280	1.3266	1431.9	1.6608	1.3027	1421.0	1.6524	
05290	1.2787	1410.0	1.6438	1.2545	1399.0	1.6350	
05300	1.2301	1388.0	1.6260	1.2054	1376.8	1.6167	
05310	1.1805	1365.6	1.6073	1.1552	1354.2	1.5975	
05320	1.1295	1342.6	1.5875	1.1034	1330.8	1.5771	
05330	1.0768	1318.8	1.5662	1.0496	1306.6	1.5550	
05340	1.0217	1293.9	1.5431	.9930	1280.9	1.5307	
05350	.9632	1267.3	1.5175	.9322	1253.1	1.5035	
05360	.8997	1238.1	1.4884	.8653	1222.2	1.4720	560. 0 psia
05370	.8286	1205.2	1.4540	.01960	441.57	.6402	
05380	.01923	419.15	.6155	.01890	397.13	.5908	
05390	.01860	375.45	.5658	.01832	354.06	.5407	
05400	.01807	332.91	.5152	.01784	311.97	.4893	
05410	.01762	291.22	.4650	.01742	270.63	.4363	
05420	.01723	250.17	.4090	.01705	229.82	.3811	
05430	.01689	209.58	.3526	.01674	189.42	.3233	
05440	.01661	169.33	.2933	.0	.0	.0	
05450	1.2343	1430.3	1.6523	1.2119	1419.3	1.6438	600. 0 psia

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
05460	1.1892	1408.3	1.6351	1.1664	1397.2	1.6262	
05470	1.1434	1386.0	1.6171	1.1201	1374.7	1.6078	
05480	1.0965	1363.3	1.5982	1.0726	1351.8	1.5884	
05490	1.0483	1340.0	1.5781	1.0235	1328.1	1.5676	
05500	.9982	1315.8	1.5565	.9723	1303.3	1.5450	
05510	.9456	1290.3	1.5329	.9180	1276.9	1.5201	
05520	.8894	1262.9	1.5065	.8595	1248.2	1.4919	
05530	.8279	1232.6	1.4762	.7944	1215.9	1.4590	
05540	.02000	464.48	.6647	.01959	441.54	.6400	600. 0 psia
05550	.01923	419.17	.6154	.01890	397.16	.5906	
05560	.01860	375.49	.5657	.01832	354.11	.5406	
05570	.01807	332.97	.5151	.01783	312.04	.4892	
05580	.01761	291.29	.4630	.01741	270.70	.4362	
05590	.01723	250.24	.4059	.01705	229.91	.3810	
05600	.01689	209.67	.3525	.01674	189.51	.3233	
05610	.01660	169.42	.2933	.0	.0	.0	
05620	1.1349	1428.2	1.6423	1.1140	1417.2	1.6337	
05630	1.0929	1406.0	1.6249	1.0715	1394.8	1.6166	
05640	1.0500	1383.5	1.6068	1.0282	1372.1	1.5973	
05650	1.0060	1360.5	1.5876	.9835	1348.7	1.5775	
05660	.9607	1335.8	1.5671	.9373	1324.5	1.5563	
05670	.9134	1312.0	1.5450	.8888	1299.1	1.5332	
05680	.8634	1285.7	1.5207	.8371	1271.8	1.5074	
05690	.8096	1257.2	1.4932	.7808	1241.8	1.4780	
05700	.7501	1225.4	1.4614	.7173	1207.6	1.4430	650. 0 psia
05710	.01999	464.48	.6645	.01958	441.60	.6398	
05720	.01922	419.21	.6152	.01889	397.21	.5905	
05730	.01859	375.55	.5656	.01831	354.18	.5404	
05740	.01806	333.04	.5150	.01782	312.12	.4891	
05750	.01761	291.38	.4629	.01741	270.71	.4361	
05760	.01722	250.34	.4058	.01705	230.01	.3810	
05770	.01689	209.77	.3524	.01674	189.62	.3232	
05780	.01660	169.53	.2932	.0	.0	.0	
05790	1.0498	1426.2	1.6330	1.0301	1415.0	1.6243	
05800	1.0102	1403.7	1.6154	.9902	1392.4	1.6064	
05810	.9699	1380.9	1.5970	.9493	1369.4	1.5874	
05820	.9284	1357.6	1.5776	.9072	1345.6	1.5673	
05830	.8855	1333.4	1.5567	.8633	1320.9	1.5457	
05840	.8405	1308.1	1.5341	.8171	1294.6	1.5219	
05850	.7928	1281.0	1.5090	.7675	1266.6	1.4952	
05860	.7409	1251.3	1.4805	.7129	1235.2	1.4644	700. 0 psia
05870	.6829	1217.8	1.4468	.02043	487.93	.6889	
05880	.01998	464.48	.6643	.01957	441.62	.6397	
05890	.01921	419.24	.6151	.01888	397.26	.5904	
05900	.01858	375.61	.5655	.01831	354.24	.5403	
05910	.01806	333.12	.5149	.01782	312.20	.4890	
05920	.01761	291.47	.4628	.01741	270.89	.4360	
05930	.01722	250.44	.4047	.01705	230.11	.3809	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
05940	.01688	209.88	.3524	.01674	189.73	.3232	700. 0 psia
05950	.01660	169.65	.2932	.0	.0	.0	
05960	.9759	1424.1	1.6242	.9573	1412.8	1.6154	
05970	.9386	1401.5	1.6065	.9196	1390.0	1.5973	
05980	.9004	1378.4	1.5878	.8809	1366.6	1.5781	
05990	.8611	1354.7	1.5681	.8409	1342.5	1.5577	
06000	.8202	1330.0	1.5468	.7990	1317.3	1.5355	
06010	.7773	1304.1	1.5236	.7547	1290.4	1.5111	
06020	.7313	1275.1	1.4977	.7069	1261.1	1.4835	
06030	.6811	1245.2	1.4680	.6536	1228.2	1.4511	
06040	.6240	1209.7	1.4325	.02042	487.90	.6887	750. 0 psia
06050	.01997	464.48	.6641	.01956	441.64	.6395	
06060	.01920	419.28	.6149	.01886	397.31	.5902	
06070	.01858	375.67	.5653	.01830	354.31	.5402	
06080	.01805	333.19	.5147	.01782	312.28	.4889	
06090	.01760	291.55	.4627	.01740	270.98	.4359	
06100	.01722	250.54	.4087	.01704	230.21	.3808	
06110	.01685	209.99	.3523	.01673	189.84	.3231	
06120	.01660	169.76	.2931	.0	.0	.0	
06130	.9113	1422.0	1.6159	.8937	1410.6	1.6070	
06140	.8759	1399.1	1.5980	.8579	1387.5	1.5887	
06150	.8376	1375.8	1.5791	.8210	1363.8	1.5692	
06160	.8021	1351.7	1.5590	.7820	1339.3	1.5484	
06170	.7630	1326.6	1.5374	.7427	1313.5	1.5258	
06180	.7218	1300.0	1.5136	.7000	1285.9	1.5007	
06190	.6774	1271.1	1.4869	.6536	1255.5	1.4720	
06200	.6283	1238.9	1.4558	.6013	1220.9	1.4381	
06210	.5717	1201.3	1.4182	.02041	487.88	.6885	800. 0 psia
06220	.01996	464.48	.6639	.01956	441.66	.6393	
06230	.01920	419.31	.6148	.01887	397.35	.5901	
06240	.01857	375.73	.5652	.01830	354.38	.5401	
06250	.01805	333.27	.5146	.01781	312.37	.4888	
06260	.01760	291.64	.4626	.01740	271.07	.4358	
06270	.01721	250.64	.4086	.01704	230.31	.3807	
06280	.01688	210.09	.3522	.01673	189.95	.3230	
06290	.01659	169.88	.2930	.0	.0	.0	
06300	.8542	1419.9	1.6089	.8375	1408.4	1.5990	
06310	.8205	1396.8	1.5899	.8033	1385.0	1.5805	
06320	.7859	1373.1	1.5708	.7681	1361.0	1.5608	
06330	.7500	1348.7	1.5504	.7315	1336.0	1.5396	
06340	.7125	1323.0	1.5283	.6929	1309.6	1.5164	
06350	.6727	1295.7	1.5039	.6516	1281.2	1.4906	850. 0 psia
06360	.6296	1265.9	1.4763	.6063	1249.7	1.4608	
06370	.5815	1232.3	1.4439	.5546	1213.3	1.4250	
06380	.02090	511.95	.7131	.02039	487.86	.6883	
06390	.01995	464.48	.6637	.01955	441.68	.6391	
06400	.01919	419.35	.6146	.01886	397.40	.5899	
06410	.01857	375.79	.5651	.01829	354.45	.5400	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
06420	.01804	333.34	.5145	.01781	312.45	.4887	
06430	.01759	291.73	.4625	.01739	271.16	.4358	
06440	.01721	250.73	.4085	.01704	230.42	.3807	850. 0 psia
06450	.01688	210.20	.3522	.01673	190.06	.3230	
06460	.01659	169.99	.2930	.0	.0	.0	
06470	.8035	1417.8	1.6004	.7875	1406.2	1.5914	
06480	.7713	1394.4	1.5822	.7548	1382.5	1.5726	
06490	.7381	1370.5	1.5628	.7210	1358.2	1.5526	
06500	.7036	1345.6	1.5421	.6858	1332.7	1.5311	
06510	.6675	1319.4	1.5195	.6486	1305.7	1.5074	
06520	.6289	1291.4	1.4945	.6084	1276.4	1.4807	
06530	.5869	1260.6	1.4659	.5640	1243.6	1.4498	
06540	.5394	1225.3	1.4326	.5126	1205.2	1.4120	
06550	.02089	511.90	.7129	.02038	487.83	.6881	900. 0 psia
06560	.01994	464.48	.6635	.01954	441.70	.6390	
06570	.01918	419.38	.6144	.01886	397.45	.5898	
06580	.01856	375.84	.5649	.01829	354.51	.5398	
06590	.01804	333.42	.5144	.01781	312.53	.4886	
06600	.01759	291.82	.4624	.01739	271.26	.4357	
06610	.01720	250.83	.4064	.01703	230.52	.3806	
06620	.01687	210.30	.3521	.01672	190.17	.3229	
06630	.01659	170.10	.2929	.0	.0	.0	
06640	.7580	1415.7	1.5932	.7427	1403.9	1.5841	
06650	.7272	1392.0	1.5746	.7114	1380.0	1.5651	
06660	.6953	1367.7	1.5552	.6789	1355.3	1.5448	
06670	.6621	1342.5	1.5341	.6449	1329.3	1.5228	
06680	.6271	1315.8	1.5111	.6088	1301.7	1.4986	
06690	.5897	1287.0	1.4853	.5696	1271.5	1.4711	
06700	.5485	1255.1	1.4557	.5259	1237.4	1.4389	
06710	.5014	1215.0	1.4201	.4744	1196.6	1.3988	
06720	.02088	511.85	.7126	.02037	487.81	.6878	950. 0 psia
06730	.01993	464.48	.6633	.01953	441.72	.6388	
06740	.01917	419.42	.6143	.01885	397.50	.5896	
06750	.01855	375.90	.5648	.01828	354.58	.5397	
06760	.01803	333.50	.5143	.01780	312.61	.4865	
06770	.01759	291.91	.4623	.01739	271.35	.4356	
06780	.01720	250.93	.4063	.01703	230.62	.3805	
06790	.01687	210.41	.3520	.01672	190.28	.3228	
06800	.01658	170.22	.2929	.0	.0	.0	
06810	.7172	1413.5	1.5863	.7024	1401.7	1.5771	
06820	.6875	1389.6	1.5677	.6722	1377.4	1.5579	
06830	.6567	1365.0	1.5478	.6409	1352.3	1.5373	
06840	.6247	1339.3	1.5263	.6080	1325.9	1.5149	
06850	.5907	1312.0	1.5028	.5729	1297.6	1.4906	1000. 0 psia
06860	.5542	1282.5	1.4764	.5346	1266.5	1.4617	
06870	.5137	1249.3	1.4457	.4913	1230.8	1.4281	
06880	.4668	1210.4	1.4082	.02144	536.69	.7375	
06890	.02086	511.79	.7124	.02036	487.79	.6876	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	VTAB (ft^3/lb)	HTAB (Btu/lb)	STAB (Btu/lb °F)	
06900	.01992	464.49	.6631	.01952	441.74	.6386	
06910	.01917	419.45	.6141	.01884	397.55	.5895	
06920	.01855	375.96	.5647	.01828	354.65	.5396	
06930	.01803	333.57	.5142	.01780	312.69	.4884	1000. 0 psia
06940	.01758	291.99	.4622	.01738	271.44	.4355	
06950	.01720	251.03	.4062	.01703	230.72	.3804	
06960	.01687	210.52	.3519	.01672	190.39	.3228	
06970	.01658	170.33	.2928	.0	.0	.0	

Figure 12. Water Superheated Fluid Properties (Cont'd)

Line No.	P (atm)	T (°C)	VLIQ (liters/mole)	VVAP (liters/mole)	HLIQ (cal/mole)	HVAP (cal/mole)
00010	.0031	20.	.241	5500.0	1520.	8700.
00020	.0133	30.	.239	1650.0	2230.	10700.
00030	.040	40.	.237	600.0	3240.	12300.
00040	.100	50.	.238	258.0	4520.	14000.
00050	.2307	60.	.24851	120.0	6232.	15261.
00060	.3428	70.	.25245	86.34	7332.	16156.
00070	.4910	80.	.25691	61.54	8449.	17061.
00080	.6824	90.	.26164	44.66	9585.	17985.
00090	.9269	100.	.26653	32.91	10740.	18920.
00100	1.000	102.6	.26779	28.26	11040.	19160.
00110	1.257	110.	.2722	22.99	11860.	19800.
00120	1.679	120.	.2794	17.44	12970.	20970.
00130	2.207	130.	.2875	13.24	14090.	21520.
00140	2.853	140.	.2964	10.42	15240.	22380.
00150	3.623	150.	.3051	8.238	16440.	23240.
00160	4.528	160.	.31570	6.5659	17810.	24210.
00170	5.579	170.	.32904	5.2218	19010.	24930.
00180	6.799	180.	.34411	4.0958	20390.	25820.
00190	8.225	190.	.35911	3.2390	21790.	26710.
00200	9.887	200.	.37996	2.5065	23150.	27500.
00210	11.603	210.	.41125	1.9213	24640.	28290.
00220	13.653	220.	.46064	1.4090	26280.	29030.
00230	14.795	223.	.49351	1.1994	26800.	29120.
00240	15.318	225.	.52251	1.0732	27350.	29090.
00250	15.961	227.95	.70738	.70738	28490.	28490.

Figure 13. FC-75 Saturated Fluid Properties -- Pressure, Temperature, Specific Volume Liquid, Specific Volume Vapor, Enthalpy Liquid, and Enthalpy Vapor*

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*This file is not used when CP-34 is the working fluid.

Line
No.

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00010 .004 .006 .008 .01  .02  .04  .06  .08  .1   .2   .4   .6  ]
00020 .8   1.   2.   3.   4.   5.   6.   7.   8.   9.   10.  11. ] PTAB(atm)
00030 12.  13.  14.  15.  16.  18.  20.  25.  30.  35.  40.  0.  ]
00040 110.  120.  130.  140.  150.  160.  170.  180.  190.  200.] TTAB(°C)
00050 210.  220.  230.  240.  250.  260.  270.  280.  290.  300.]
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Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
00060	19.70	67.94	7832.42	20.69	70.49	8036.84	0.004 psia
00070	21.68	72.99	8241.26	22.69	75.44	8445.69	
00080	23.70	77.86	8650.11	24.71	80.23	8854.53	
00090	25.74	82.57	9058.95	26.77	84.86	9263.37	
00100	27.80	87.13	9467.79	28.84	89.35	9672.22	
00110	29.89	91.55	9876.64	30.95	93.71	10081.06	
00120	32.01	95.85	10285.5	33.08	97.95	10489.9	
00130	34.16	100.03	10694.3	35.24	102.08	10898.8	
00140	36.34	104.11	11103.2	37.43	106.11	11307.6	
00150	38.54	108.09	11512.0	39.65	110.04	11716.4	
00160	19.72	67.20	5221.61	20.71	69.75	5357.89	0.006 psia
00170	21.71	72.25	5494.18	22.71	74.70	5630.46	
00180	23.72	77.12	5766.74	24.73	79.49	5903.02	
00190	25.76	81.82	6039.30	26.79	84.12	6175.58	
00200	27.82	86.38	6311.86	28.86	88.61	6448.14	
00210	29.91	90.81	6584.43	30.97	92.97	6720.71	
00220	32.03	95.11	6856.99	33.10	97.21	6993.27	
00230	34.18	99.29	7129.55	35.26	101.34	7265.83	
00240	36.36	103.37	7402.11	37.45	105.37	7538.39	
00250	38.56	107.35	7674.67	39.67	109.30	7810.96	
00260	19.73	66.67	3916.21	20.72	69.22	4018.42	0.008 psia
00270	21.72	71.72	4120.63	22.72	74.18	4222.84	
00280	23.73	76.59	4325.05	24.75	78.96	4427.26	
00290	25.77	81.30	4529.48	26.80	83.60	4631.69	
00300	27.84	85.86	4733.90	28.88	88.09	4836.11	
00310	29.93	90.28	4938.32	30.99	92.45	5040.53	
00320	32.05	94.58	5142.74	33.12	96.69	5244.95	
00330	34.20	98.76	5347.16	35.28	100.82	5449.37	
00340	36.37	102.84	5551.58	37.47	104.84	5653.80	
00350	38.57	106.82	5756.01	39.68	108.78	5858.22	
00360	19.74	66.26	3132.97	20.73	68.81	3214.74	0.01 psia
00370	21.73	71.31	3296.51	22.73	73.77	3378.27	
00380	23.74	76.18	3460.04	24.76	78.56	3541.81	
00390	25.78	80.89	3623.58	26.81	83.19	3705.35	
00400	27.85	85.45	3787.12	28.89	87.68	3868.89	
00410	29.94	89.87	3950.66	31.00	92.04	4032.42	

Figure 14. FC-75 Superheated Fluid Properties -- Pressure Temperature, Enthalpy, Entropy, and Specific Volume*

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*This file is not used when CP-34 is the working fluid.

Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
00420	32.06	91.17	4114.19	33.13	96.28	4195.96	0.01 psia
00430	34.21	98.36	4277.73	35.29	100.41	4359.50	
00440	36.38	102.43	4441.27	37.48	104.44	4523.04	
00450	38.58	106.41	4604.80	39.69	108.37	4686.57	
00460	19.78	64.99	1566.48	20.76	67.54	1607.37	0.02 psia
00470	21.76	70.04	1648.25	22.76	72.49	1689.14	
00480	23.77	74.91	1730.02	24.79	77.28	1770.91	
00490	25.81	79.62	1811.79	26.84	81.91	1852.67	
00500	27.88	84.18	1893.56	28.92	86.40	1934.44	
00510	29.97	88.60	1975.33	31.03	90.76	2016.21	
00520	32.09	92.90	2057.10	33.16	95.00	2097.98	
00530	34.24	97.08	2138.86	35.32	99.13	2179.75	
00540	36.41	101.16	2220.63	37.51	103.16	2261.52	
00550	38.61	105.14	2302.40	39.72	107.09	2343.29	
00560	19.80	63.71	783.24	20.79	66.26	803.68	0.04 psia
00570	21.79	68.76	824.13	22.79	71.22	844.57	
00580	23.80	73.63	865.01	24.82	76.00	885.45	
00590	25.84	78.34	905.90	26.87	80.64	926.34	
00600	27.91	82.90	946.78	28.95	85.13	967.22	
00610	30.00	87.32	987.66	31.06	89.49	1008.11	
00620	32.12	91.62	1028.55	33.19	93.73	1048.99	
00630	34.27	95.80	1069.43	35.35	97.86	1089.87	
00640	36.44	99.88	1110.32	37.54	101.88	1130.76	
00650	38.64	103.86	1151.20	39.75	105.82	1171.64	
00660	19.82	62.96	522.16	20.81	65.50	535.79	0.06 psia
00670	21.80	68.01	549.42	22.81	70.46	563.05	
00680	23.82	72.88	576.67	24.83	75.25	590.30	
00690	25.85	77.58	603.93	26.88	79.88	617.56	
00700	27.92	82.14	631.19	28.96	84.37	644.81	
00710	30.01	86.57	658.44	31.07	88.73	672.07	
00720	32.13	90.87	685.70	33.20	92.97	699.33	
00730	34.28	95.05	712.95	35.36	97.11	726.58	
00740	36.45	99.13	740.21	37.55	101.13	753.84	
00750	38.65	103.11	767.47	39.77	105.06	781.10	
00760	19.83	62.42	391.62	20.82	64.97	401.84	0.08 psia
00770	21.81	67.47	412.06	22.82	69.93	422.28	
00780	23.82	72.34	432.51	24.84	74.71	442.73	
00790	25.86	77.05	452.95	26.89	79.34	463.17	
00800	27.93	81.61	473.39	28.97	83.84	483.61	
00810	30.02	86.03	493.83	31.08	88.21	504.05	
00820	32.14	90.33	514.27	33.21	92.44	524.50	
00830	34.29	94.51	534.72	35.37	96.57	544.94	
00840	36.46	98.59	555.16	37.56	100.59	565.38	
00850	38.66	102.57	575.60	39.77	104.53	585.82	
00860	19.83	62.00	313.30	20.82	64.55	321.47	0.1 psia
00870	21.82	67.05	329.65	22.82	69.51	337.83	
00880	23.83	71.92	346.00	24.85	74.30	354.18	

Figure 14. FC-75 Superheated Fluid Properties (Cont'd)

Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
00890	25.67	76.63	362.36	26.90	78.93	370.53	0.1 psia
00900	27.94	81.19	378.71	28.98	83.42	386.89	
00910	30.03	85.61	395.07	31.09	87.78	403.24	
00920	32.15	89.91	411.42	33.22	92.02	419.60	
00930	34.30	94.10	427.77	35.38	96.15	435.95	
00940	36.47	98.18	444.13	37.57	100.18	452.30	
00950	38.67	102.15	460.46	39.78	104.11	468.66	
00960	19.85	60.79	156.65	20.84	63.25	160.74	0.2 psia
00970	21.84	65.75	164.83	22.84	68.20	168.91	
00980	23.85	70.62	173.00	24.86	72.99	177.09	
00990	25.89	75.33	181.18	26.92	77.62	185.27	
01000	27.95	79.89	189.36	29.00	82.11	193.44	
01010	30.05	84.31	197.53	31.10	86.47	201.62	
01020	32.17	88.61	205.71	33.24	90.71	209.80	
01030	34.31	92.79	213.89	35.40	94.84	217.97	
01040	36.49	96.87	222.06	37.58	98.87	226.15	
01050	38.69	100.85	230.24	39.80	102.80	234.33	
01060	19.85	59.37	78.32	20.84	61.92	80.37	0.4 psia
01070	21.84	64.42	82.41	22.84	66.87	84.46	
01080	23.85	69.29	86.50	24.87	71.66	88.55	
01090	25.89	74.00	90.59	26.92	76.29	92.63	
01100	27.95	78.55	94.68	29.00	80.78	96.72	
01110	30.05	82.98	98.77	31.10	85.14	100.81	
01120	32.17	87.28	102.85	33.24	89.38	104.90	
01130	34.31	91.46	106.94	35.40	93.51	108.99	
01140	36.49	95.54	111.03	37.58	97.54	113.08	
01150	38.69	99.52	115.12	39.80	101.47	117.16	
01160	19.85	58.58	52.22	20.84	61.13	53.58	0.6 psia
01170	21.83	63.63	54.94	22.84	66.08	56.30	
01180	23.84	68.50	57.67	24.86	70.87	59.03	
01190	25.88	73.21	60.39	26.91	75.50	61.76	
01200	27.95	77.76	63.12	28.99	79.99	64.48	
01210	30.04	82.19	65.84	31.10	84.35	67.21	
01220	32.16	86.49	68.57	33.23	88.59	69.93	
01230	34.31	90.67	71.30	35.39	92.72	72.66	
01240	36.48	94.75	74.02	37.58	96.75	75.38	
01250	38.68	98.73	76.75	39.79	100.68	78.11	
01260	19.84	58.01	39.16	20.83	60.56	40.18	0.8 psia
01270	21.83	63.06	41.21	22.83	65.52	42.23	
01280	23.84	67.93	43.25	24.85	70.30	44.27	
01290	25.88	72.64	45.29	26.91	74.94	46.32	
01300	27.94	77.20	47.34	28.98	79.43	48.36	
01310	30.03	81.62	49.38	31.09	83.79	50.41	
01320	32.15	85.92	51.43	33.22	88.03	52.45	
01330	34.30	90.10	53.47	35.39	92.16	54.49	
01340	36.48	94.18	55.52	37.57	96.18	56.54	
01350	38.68	98.16	57.56	39.79	100.12	58.58	

Figure 14. FC-75 Superheated Fluid Properties (Cont'd)

Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
01360	19.89	57.70	29.84	21.87	60.23	30.80	1. 0 psia
01370	21.87	62.37	31.76	22.86	65.17	32.71	
01380	23.87	67.58	33.66	24.88	69.95	34.54	
01390	25.90	72.27	35.60	26.93	74.56	36.50	
01400	27.96	76.82	37.42	29.00	79.04	38.33	
01410	30.05	81.22	39.25	31.10	83.38	40.13	
01420	32.16	85.51	41.01	33.23	87.61	41.90	
01430	34.30	89.68	42.76	35.38	91.73	43.64	
01440	36.47	93.74	44.50	37.56	95.74	45.34	
01450	38.66	97.71	46.18	39.77	99.66	47.03	
01460	0.	0.	0.	0.	0.	0.	2. 0 psia
01470	21.59	61.89	14.96	22.61	63.58	15.54	
01480	23.63	66.20	16.10	24.73	68.33	16.65	
01490	25.76	70.72	17.26	26.80	73.01	17.77	
01500	27.84	75.27	18.29	28.89	77.49	18.79	
01510	29.94	79.68	19.30	31.00	81.87	19.80	
01520	32.07	84.03	20.25	33.15	86.14	20.72	
01530	34.23	88.25	21.18	35.32	90.33	21.66	
01540	36.42	92.36	22.12	37.52	94.36	22.57	
01550	38.62	96.33	23.01	39.73	98.28	23.45	
01560	0.	0.	0.	0.	0.	0.	3. 0 psia
01570	0.	0.	0.	0.	0.	0.	
01580	23.38	64.79	10.12	24.55	67.17	10.62	
01590	25.60	69.62	11.05	26.66	71.94	11.44	
01600	27.71	74.22	11.83	28.77	76.45	12.21	
01610	29.83	78.65	12.58	30.90	80.87	12.94	
01620	31.98	83.06	13.25	33.06	85.19	13.59	
01630	34.15	87.32	13.91	35.25	89.42	14.26	
01640	36.36	91.46	14.60	37.46	93.46	14.92	
01650	38.57	95.44	15.23	39.68	97.39	15.53	
01660	0.	0.	0.	0.	0.	0.	4. 0 psia
01670	0.	0.	0.	0.	0.	0.	
01680	0.	0.	0.	24.33	66.17	7.501	
01690	25.40	68.70	7.873	26.50	71.07	8.211	
01700	27.57	73.39	8.543	28.63	75.64	8.854	
01710	29.71	77.66	9.156	30.79	80.16	9.517	
01720	31.88	82.32	9.710	32.97	84.47	9.974	
01730	34.06	86.62	10.24	35.17	88.73	10.53	
01740	36.28	90.77	10.79	37.40	92.78	11.05	
01750	38.51	94.77	11.30	39.62	96.72	11.54	
01760	0.	0.	0.	0.	0.	0.	5. 0 psia
01770	0.	0.	0.	0.	0.	0.	
01780	0.	0.	0.	0.	0.	0.	
01790	25.17	67.83	5.917	26.31	70.30	6.228	
01800	27.41	72.67	6.527	28.49	74.99	6.804	
01810	29.58	77.21	7.068	30.67	79.46	7.350	
01820	31.77	81.70	7.561	32.87	83.87	7.784	

Figure 14 . FC-75 Superheated Fluid Properties (Cont'd)

Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
01830	33.97	86.03	8.010	35.08	88.15	8.257	5.0 psia
01840	36.20	90.21	8.475	37.32	92.23	8.692	
01850	38.44	94.22	8.910	39.56	96.18	9.110	
01860	0.	0.	0.	0.	0.	0.	6.0 psia
01870	0.	0.	0.	0.	0.	0.	
01880	0.	0.	0.	0.	0.	0.	
01890	0.	0.	0.	26.09	69.53	4.873	
01900	27.23	71.99	5.151	28.33	74.36	5.408	
01910	29.44	76.62	5.654	30.55	78.89	5.923	
01920	31.66	81.16	6.112	32.77	83.34	6.316	
01930	33.87	85.51	6.519	34.99	87.66	6.732	
01940	36.12	89.72	6.923	37.25	91.75	7.116	
01950	38.26	93.75	7.302	39.49	95.72	7.482	
01960	0.	0.	0.	0.	0.	0.	7.0 psia
01970	0.	0.	0.	0.	0.	0.	
01980	0.	0.	0.	0.	0.	0.	
01990	0.	0.	0.	0.	0.	0.	
02000	27.02	71.30	4.145	28.16	73.74	4.393	
02010	29.29	76.05	4.628	30.43	78.36	4.884	
02020	31.55	80.67	5.066	32.67	82.87	5.262	
02030	33.77	85.05	5.451	34.90	87.31	5.638	
02040	36.03	89.29	5.811	37.17	91.33	5.947	
02050	38.28	93.34	6.149	39.41	95.31	6.317	
02060	0.	0.	0.	0.	0.	0.	8.0 psia
02070	0.	0.	0.	0.	0.	0.	
02080	0.	0.	0.	0.	0.	0.	
02090	0.	0.	0.	0.	0.	0.	
02100	26.77	70.56	3.367	27.96	73.13	3.615	
02110	29.13	75.50	3.844	30.29	77.85	4.090	
02120	31.42	80.20	4.279	32.55	82.43	4.406	
02130	33.67	84.62	4.642	34.81	86.80	4.817	
02140	35.94	88.89	4.979	37.08	90.94	5.139	
02150	38.20	92.96	5.287	39.34	94.94	5.443	
02160	0.	0.	0.	0.	0.	0.	9.0 psia
02170	0.	0.	0.	0.	0.	0.	
02180	0.	0.	0.	0.	0.	0.	
02190	0.	0.	0.	0.	0.	0.	
02200	0.	0.	0.	27.73	72.47	2.994	
02210	28.94	74.93	3.219	30.14	77.37	3.460	
02220	31.29	79.75	3.665	32.43	82.00	3.840	
02230	33.56	84.21	4.010	34.71	86.42	4.173	
02240	35.85	88.52	4.329	37.00	90.58	4.475	
02250	38.12	92.61	4.618	39.26	94.60	4.761	
02260	0.	0.	0.	0.	0.	0.	10.0 psia
02270	0.	0.	0.	0.	0.	0.	
02280	0.	0.	0.	0.	0.	0.	
02290	0.	0.	0.	0.	0.	0.	

Figure 14. FC-75 Superheated Fluid Properties (Cont'd)

Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
02300	0.	0.	0.	0.	0.	0.	10. 0 psia
02310	28.73	74.33	2.709	29.97	76.87	2.944	
02320	31.15	79.31	3.163	32.30	81.59	3.313	
02330	33.45	83.82	3.500	34.60	86.05	3.655	
02340	35.76	88.16	3.804	36.91	90.23	3.943	
02350	38.04	92.28	4.062	39.18	94.28	4.213	
02360	0.	0.	0.	0.	0.	0.	11. 0 psia
02370	0.	0.	0.	0.	0.	0.	
02380	0.	0.	0.	0.	0.	0.	
02390	0.	0.	0.	0.	0.	0.	
02400	0.	0.	0.	0.	0.	0.	
02410	28.49	73.70	2.288	29.78	76.55	2.513	
02420	30.99	78.65	2.742	32.17	81.17	2.911	
02430	33.32	83.43	3.088	34.50	85.69	3.229	
02440	35.66	87.62	3.373	36.82	89.90	3.511	
02450	37.95	91.96	3.645	39.10	93.98	3.768	
02460	0.	0.	0.	0.	0.	0.	12. 0 psia
02470	0.	0.	0.	0.	0.	0.	
02480	0.	0.	0.	0.	0.	0.	
02490	0.	0.	0.	0.	0.	0.	
02500	0.	0.	0.	0.	0.	0.	
02510	28.22	73.01	1.[illegible]5	29.57	75.79	2.132	
02520	30.82	78.37	2.3[illegible]7	32.02	80.76	2.554	
02530	33.20	83.06	2.72[illegible]	34.38	85.34	2.873	
02540	35.56	87.49	3.0[illegible]3	36.72	89.58	3.1[illegible]1	
02550	37.86	91.65	3.278	39.01	93.64	3.36[illegible]	
02560	0.	0.	0.	0.	0.	0.	13. 0 psia
02570	0.	0.	0.	0.	0.	0.	
02580	0.	0.	0.	0.	0.	0.	
02590	0.	0.	0.	0.	0.	0.	
02600	0.	0.	0.	0.	0.	0.	
02610	0.	0.	0.	29.35	75.19	1.8[illegible]3	
02620	3[illegible]	77.[illegible]	2.[illegible]2	31.36	80.33	2.29[illegible]	
02630	33.[illegible]6	82.55	2.424	34.27	85.00	2.572	
02640	35.35	87.15	2.7[illegible]9	3[illegible].63	89.27	2.846	
02650	37.77	91.36	2.9[illegible]7	3[illegible].93	93.41	3.062	
02660	0.	0.	0.	0.	0.	0.	14. 0 psia
02670	0.	0.	0.	0.	0.	0.	
02680	0.	0.	0.	0.	0.	0.	
02690	0.	0.	0.	0.	0.	0.	
02700	0.	0.	0.	0.	0.	0.	
02710	0.	0.	0.	0.	0.	0.	
02720	30.40	77.34	1.745	31.68	79.88	1.986	
02730	32.91	82.29	2.162	34.14	84.65	2.312	
02740	35.34	86.83	2.448	36.53	88.97	2.581	
02750	37.[illegible]8	91.07	2.700	38.84	93.13	2.812	
02760	0.	0.	0.	0.	0.	0.	15. 0 psia

Figure 14 . FC-75 Superheated Fluid Properties (Cont'd)

Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
02770	0.	0.	0.	0.	0.	0.	15. 0 psia
02780	0.	0.	0.	0.	0.	0.	
02790	0.	0.	0.	0.	0.	0.	
02800	0.	0.	0.	0.	0.	0.	
02810	0.	0.	0.	0.	0.	0.	
02820	30.08	76.63	1.450	31.46	79.37	1.724	
02830	32.76	81.89	1.936	34.01	84.31	2.081	
02840	35.23	86.51	2.222	36.42	88.68	2.354	
02850	37.58	90.79	2.470	38.75	92.87	2.576	
02860	0.	0.	0.	0.	0.	0.	16. 0 psia
02870	0.	0.	0.	0.	0.	0.	
02880	0.	0.	0.	0.	0.	0.	
02890	0.	0.	0.	0.	0.	0.	
02900	0.	0.	0.	0.	0.	0.	
02910	0.	0.	0.	0.	0.	0.	
02920	29.61	76.16	1.106	31.18	78.86	1.470	
02930	32.58	81.47	1.727	33.87	83.96	1.883	
02940	35.11	86.20	2.017	36.32	88.39	2.152	
02950	37.48	90.52	2.262	38.66	92.61	2.371	
02960	0.	0.	0.	0.	0.	0.	18. 0 psia
02970	0.	0.	0.	0.	0.	0.	
02980	0.	0.	0.	0.	0.	0.	
02990	0.	0.	0.	0.	0.	0.	
03000	0.	0.	0.	0.	0.	0.	
03010	0.	0.	0.	0.	0.	0.	
03020	28.99	75.41	.502	30.61	78.00	1.004	
03030	32.16	80.77	1.361	33.59	83.24	1.545	
03040	34.67	85.58	1.670	36.10	87.81	1.799	
03050	37.28	89.97	1.912	38.46	92.08	2.027	
03060	0.	0.	0.	0.	0.	0.	20. 0 psia
03070	0.	0.	0.	0.	0.	0.	
03080	0.	0.	0.	0.	0.	0.	
03090	0.	0.	0.	0.	0.	0.	
03100	0.	0.	0.	0.	0.	0.	
03110	0.	0.	0.	0.	0.	0.	
03120	28.65	74.50	.459	30.21	77.14	.644	
03130	31.76	80.11	1.022	33.31	82.60	1.256	
03140	34.61	84.98	1.392	35.86	87.24	1.517	
03150	37.05	89.43	1.636	38.25	91.56	1.745	
03160	0.	0.	0.	0.	0.	0.	25. 0 psia
03170	0.	0.	0.	0.	0.	0.	
03180	0.	0.	0.	0.	0.	0.	
03190	0.	0.	0.	0.	0.	0.	
03200	0.	0.	0.	0.	0.	0.	
03210	0.	0.	0.	0.	0.	0.	
03220	27.98	72.68	.425	29.47	75.40	.481	

Figure 14 . FC-75 Superheated Fluid Properties (Cont'd)

Line No.	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	HTAB (kcal/mole)	STAB (cal/mole-°C)	VTAB (liters/mole)	
03230	30.96	78.27	.564	32.43	80.82	.726	25.0 psia
03240	33.84	83.28	.890	35.20	85.58	1.020	
03250	36.44	88.04	1.133	37.66	90.22	1.250	
03260	0.	0.	0.	0.	0.	0.	30.0 psia
03270	0.	0.	0.	0.	0.	0.	
03280	0.	0.	0.	0.	0.	0.	
03290	0.	0.	0.	0.	0.	0.	
03300	0.	0.	0.	0.	0.	0.	
03310	0.	0.	0.	0.	0.	0.	
03320	27.54	71.39	.408	28.90	74.15	.438	
03330	30.37	76.81	.484	31.74	79.39	.550	
03340	33.08	81.71	.644	34.53	84.18	.750	
03350	35.80	86.69	.858	37.04	88.90	.963	
03360	0.	0.	0.	0.	0.	0.	35.0 psia
03370	0.	0.	0.	0.	0.	0.	
03380	0.	0.	0.	0.	0.	0.	
03390	0.	0.	0.	0.	0.	0.	
03400	0.	0.	0.	0.	0.	0.	
03410	0.	0.	0.	0.	0.	0.	
03420	27.30	70.69	.405	28.60	73.28	.428	
03430	30.00	75.99	.455	31.33	78.39	.481	
03440	32.64	80.77	.541	34.01	83.13	.611	
03450	35.26	85.56	.685	36.51	87.71	.759	
03460	0.	0.	0.	0.	0.	0.	40.0 psia
03470	0.	0.	0.	0.	0.	0.	
03480	0.	0.	0.	0.	0.	0.	
03490	0.	0.	0.	0.	0.	0.	
03500	0.	0.	0.	0.	0.	0.	
03510	0.	0.	0.	0.	0.	0.	
03520	27.18	70.26	.329	28.46	72.82	.413	
03530	29.77	75.37	.433	31.05	77.78	.454	
03540	32.37	80.17	.487	33.68	82.40	.537	
03550	34.89	84.77	.591	36.12	86.88	.649	

Figure 14 . FC-75 Superheated Fluid Properties (Cont'd)